



Missouri Statewide Wildlife Vehicle Collision Study

Wildlife Vehicle Collision Reduction Analysis &
Hot Spot Mitigation Measure Feasibility Study

Missouri, USA
February 27, 2026

Prepared on behalf of the Missouri Department
of Transportation by:

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Acknowledgements

The project team would like to thank and acknowledge the following agencies and individuals for dedicating their guidance and support in developing this planning effort. A listing of the project team and technical advisory committee members is found below.

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Executive Summary

The Missouri Department of Transportation (MoDOT) initiated this statewide study (Study) of wildlife vehicle collision (WVC) analysis, hot spot ranking, and mitigation measure feasibility to help inform MoDOT transportation planning. The overall goal of the Study was to conduct a statewide multi-species analysis to develop, refine, and prioritize recommendations to address WVC hot spots in Missouri. Results obtained from the Study will be used to develop, design, permit, and construct WVC mitigation projects in Missouri with the overall goal of reducing WVCs statewide while promoting roadway safety and improving habitat connectivity. Additionally, projects identified with this Study could be eligible for specific funding through FHWA Wildlife Road Crossing Program funds, if this program is included in the next transportation act, or other funding sources.

Prior to the Study, MoDOT identified a list of 25 at-risk Missouri wildlife species as priority species that would benefit the most from a reduction of WVCs. These species were the focus of an analysis of Missouri ecology conducted during the Study to determine locations of potential and occupied suitable habitat throughout the state.

The Study combined information on MoDOT roadways with previously collected data detailing WVCs and carcasses to identify locations where WVCs frequently and regularly occur in Missouri, referred to as “hot spots.” A spatial analysis was conducted using the Optimized Hot Spot Analysis (OHSA) to identify and rank WVC hot spots and meet the Study’s objectives. Half mile segments of all MoDOT administered roads were paired with the reported wildlife crashes point data to evaluate crash rates for every segment. The hot spot analysis identified 4,367 to 16,974 significant hot spots throughout the state, which consisted of neighboring half-mile segments with greater wildlife crash rates than neighboring segments.

In order to identify and rank wildlife vehicle conflict hot spots at a statewide scale, a suite of factors that quantitatively represented transportation safety, wildlife ecology variables related to wildlife-vehicle conflict, and feasibility for mitigation measures were intersected with the half-mile road segments. Each road segment received a score for each criterion, and the sum total for all criteria was then fed into the OHSA for a final hot spot map of prioritized wildlife-vehicle conflict areas. This process identified 627 priority segments. The priority segments were sorted by their final score and the Top 100 segments were then qualitatively evaluated for feasibility (based on land use and protection), constructability, and the upcoming State Transportation Program (STIP) to generate a ranked list of the Top 10 wildlife vehicle conflict areas across the state of Missouri.

An alternatives analysis was then completed, including recommended improvements to the Top 10 segments to reduce WVCs, and Benefit-Cost analysis of the proposed alternatives. The Top 10 segments were also reviewed for potential environmental considerations. The Study concluded with the development of an implementation plan for both the Top 10 segments and future areas of WVC concern to provide MoDOT and partners with details on how to include wildlife considerations in future transportation planning, as well as how to plan, fund, design, construct, and maintain wildlife crossing structures and other mitigation efforts.



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Acronyms

AADT	Annual Average Daily Traffic
AFB	Airforce Base
AFWA	Association of Fish and Wildlife Agencies
AOP	Aquatic Organism Passage
APP	Area of Persistent Poverty
ARC	Animal Road Crossing
BACI	Before-After-Control-Impact
BGEPA	Bald and Golden Eagle Protection Act
BIP	Bridge Investment Program
BLM	Bureau of Land Management
BMP	Best Management Practice
BUILD	Better Utilizing Investments to Leverage Development
CCS	Comprehensive Conservation Strategy
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CT	Census Tract
CWA	Clean Water Act
DNR	Department of Natural Resources
DoD	Department of Defense
DOT	Department of Transportation
EPG	Engineering Policy Guide
ESA	Endangered Species Act
FE	Federally Endangered
FT	Federally Threatened
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GAP	Gap Analysis Project
HSIP	Highway Safety Improvement Program
INFRA	Nationally Significant Multimodal Freight and Highway Projects
IPaC	Information for Planning and Consultation
IS	Interstate
LLF	Land Learning Foundation
LRTP	Long-Range Transportation Plan
LULC	Land Use Land Cover
LWCF	Land and Water Conservation Fund
MBTA	Migratory Bird Treaty Act
MDC	Missouri Department of Conservation
MO	Missouri State Highway
MoDNR	Missouri Department of Natural Resources
MOCARS	Missouri Crash Analysis Reporting System



MoDOT	Missouri Department of Transportation
MP	Mile Post
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
MSHP	Missouri State Highway Patrol
MSS	Missouri Speleological Survey
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NHD	National Hydrography Dataset
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOFO	Notice of Funding Opportunity
NPS	National Park Service
NRCS	National Resources Conservation Service
NRHP	National Register of Historic Places
NSFLTP	Nationally Significant Federal Lands and Tribal Projects
NWF	National Wildlife Federation
NFWF	National Fish and Wildlife Foundation
NWI	National Wetlands Inventory
PAB	Palustrine Aquatic Bed
PAD-US	Protected Areas Database of the United States
PEM	Palustrine Emergent Wetlands
PFO	Palustrine Forested Wetlands
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation
PSS	Palustrine Shrub Wetlands
PUB	Palustrine Unconsolidated Bottom
RAISE	Rebuilding American Infrastructure with Sustainability and Equity
RCRA	Resource Conservation and Recovery Act
RES	Request for Environmental Services
ROaDS	Roadkill Observation and Data System
ROW	Right Of Way
RPO	Regional Planning Organizations
RT	Missouri Secondary State Route
SAFER	Safety Assessment for Every Roadway
SARA	Superfund Amendments and Reauthorization Act
SE	State Endangered
SEMA	Missouri State Emergency Management Agency
SHPO	State Historic Preservation Office
SOCC	Species of Conservation Concern



STIP	State Transportation Improvement Program
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TMS	Transportation Management Systems
TTPSF	Tribal Transportation Program Safety Fund
USACE	U.S. Army Corps of Engineers
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USDOI	U.S. Department of the Interior
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WCPP	Wildlife Crossings Pilot Program
WDS	Wildlife Detection Driver Warning System
WOTUS	Waters of the U.S.
WRRC	Wildlife Roadsharing Resource Centre
WVC	Wildlife Vehicle Collision

1 Introduction

1.1 Purpose and Need

The Missouri Department of Transportation (MoDOT) initiated this statewide study (Study) of wildlife vehicle collision (WVC) analysis, hot spot ranking, and mitigation measure feasibility to help inform MoDOT transportation planning. This first of its kind analysis in Missouri includes reported wildlife-vehicle crash data, carcass data, previously completed studies, wildlife linkage zones, wildlife habitat blocks, and industry best-management practices and will pave the way for future wildlife crossing mitigation and accommodations. The results of this Study will also further the Federal Highway Administration's (FHWA) mission: "improve safety and mobility on our nation's highways through national leadership, innovation, and program delivery."

1.2 Study Objectives

The overall goal of the Study is to conduct a statewide multi-species analysis to develop, refine, and prioritize recommendations to address WVC hot spots in Missouri. Results obtained from the Study will be used to develop, design, permit, and construct WVC mitigation projects in Missouri with the overall goal of reducing WVCs statewide while promoting roadway safety and improving habitat connectivity. Additionally, projects identified with this Study could be eligible for specific funding with additional Wildlife Road Crossings Program funds or other funding sources. Specific objectives of this study were to:

- 1) Identify significant WVC hot spots that are potential conflict areas where wildlife and motorists are at greatest risk for vehicle collisions, as well as where wildlife may need to move across roads, thus identifying conflict areas that involve not only potential future crash areas but areas of greatest wildlife connectivity needs;
- 2) Prioritize the most significant hot spot areas along highways where there are key conflicts with wildlife and vehicles, including those affecting threatened and endangered species and special status species;
- 3) Present a wildlife mitigation solutions library for reference to outline recommended solutions;
- 4) Identify the top 10 wildlife-vehicle conflict hot spot areas and proper project-level scopes and cost estimates to implement the recommended solutions; and
- 5) Develop a transportation planning approach that allows MoDOT to plan more holistically for wildlife presence and landscape connectivity in the face of increasing human populations and vehicle traffic.

1.3 Background and History

The FHWA posted a Notice of Funding Opportunity (NOFO) for the Fiscal Years 2022-2023 Wildlife Crossings Pilot Program (WCPP) on April 4, 2023. The WCPP enabled eligible entities to apply for federal funding enacted under the Bipartisan Infrastructure Law, which authorized \$350 million in wildlife crossing project funding from Federal Fiscal Years 2022-2026. The objective of the WCPP is to reduce WVCs while improving habitat connections for terrestrial and aquatic communities.



In March 2022, the MoDOT Design Environmental section obtained crash data from the Highway Safety and Traffic division. Together with MoDOT GIS staff, MoDOT conducted a preliminary hot spot analysis of WVCs in Missouri. Concurrently, MoDOT utilized the University of California-Davis wildlife crossing calculator to conduct a hot spot analysis. While the analysis was beneficial in locating preliminary information on WVC hot spot locations, decisions on which locations to address and measures to use need to be based on a rigorous, methodological approach to meet an effective reduction in WVC. MoDOT wanted to conduct a more detailed analysis of available data to effectively identify and address high WVC conflict areas.

MoDOT, in cooperation with the Missouri Department of Conservation (MDC) and Land Learning Foundation (LLF), with support from state and federal natural resources management agencies, non-governmental organizations (NGOs), and interested partners, submitted an application for this grant to the amount of \$320,000 which was announced on December 5, 2023.

1.4 Study Process

The Study was divided into two parts. Part one focused on analysis of available datasets to understand current and future conditions, identify and rank WVC hot spots, and create a list of statewide wildlife-vehicle conflict needs. Part two developed evaluation criteria for prioritizing WVCs, alternatives analysis, recommended mitigation, and provided opportunity for public comment.

A Technical Advisory Committee (TAC) was established to closely coordinate the Study and provide project reviews, comments, and recommendations. The TAC consists of representatives from the following groups:

- MoDOT Research, Transportation Planning, Highway Safety and Traffic, Maintenance, Design – Environmental and Historic Preservation, and Policy and Innovations
- MDC - Policy Coordination, Science, and Statewide Resource Management
- Missouri State Highway Patrol (MSHP) - Field Operations Bureau
- Animal Road Crossing (ARC) Solutions
- National Wildlife Federation (NWF) Regional Connectivity Coordinator
- U.S. Forest Service - Mark Twain National Forest
- U.S. Fish and Wildlife Service (USFWS) - Ecological Services
- U.S. Geological Survey (USGS) - Research
- National Park Service (NPS) - Rivers, Trails and Conservation Assistance Program
- FHWA - Safety and Mobility

MoDOT and the TAC identified a list of 25 at-risk Missouri wildlife species as priority species for the Study, consisting of species that would benefit the most from a reduction of WVCs (**Table 1-1**). The list was developed from the Missouri Species of Conservation Concern (SOCC) Checklist (a list of rare and/or declining species in Missouri) and the USFWS Information for Planning and Consultation (IPaC) tool (a database of federally threatened, endangered, and candidate species in Missouri). The list also includes species that are designated as MDC focal species (species for which a management plan has been developed).



Table 1-1: Priority Species

Common Name	Scientific Name	Status ¹
Pondberry	<i>Lindera melissifolia</i>	SE, FE, SOCC
Bald Eagle	<i>Haliaeetus leucocephalus</i>	SOCC
Indiana Bat	<i>Myotis sodalis</i>	SE, FE, SOCC
Black-Tailed Jackrabbit	<i>Lepus californicus</i>	SE, SOCC
Franklin's Ground Squirrel	<i>Poliocitellus franklinii</i>	SOCC
Thirteen-Lined Ground Squirrel	<i>Ictidomys tridecemlineatus</i>	SOCC
Least Weasel	<i>Mustela nivalis</i>	SOCC
Long-Tailed Weasel	<i>Mustela frenata</i>	SOCC
American Badger	<i>Taxidea taxus</i>	SOCC
Plains Spotted Skunk	<i>Spilogale putorius</i>	SE, SOCC
White-Tailed Deer	<i>Odocoileus virginianus</i>	MDC Focal Species
American Black Bear	<i>Ursus americanus</i>	MDC Focal Species; SOCC
Elk	<i>Cervus canadensis</i>	MDC Focal Species
Great Plains Toad	<i>Anaxyrus cognatus</i>	SOCC
Northern Leopard Frog	<i>Lithobates pipiens</i>	SOCC
Eastern Tiger Salamander	<i>Ambystoma tigrinum</i>	SOCC
Alligator Snapping Turtle	<i>Macrochelys temminckii</i>	Proposed FT, SOCC
Blanding's Turtle	<i>Emydoidea blandingii</i>	SE, SOCC
Western Chicken Turtle	<i>Deirochelys reticularia miaria</i>	SE, SOCC
Western Foxsnake	<i>Pantherophis ramspotti</i>	SOCC
Western Mudsnake	<i>Farancia abacura reinwardtii</i>	SOCC
Eastern Massasauga Rattlesnake	<i>Sistrurus catenatus</i>	SE, FT, SOCC
Kirtland's Snake	<i>Clonophis kirtlandii</i>	SOCC
Niangua Darter	<i>Etheostoma nianguae</i>	SE, FT, SOCC
Topeka Shiner	<i>Miniellus topeka</i>	SE, FE, SOCC

¹SE=state endangered; FT=federally threatened; FE=federally endangered, SOCC = Species of Conservation Concern

2 Current Conditions

An understanding of the current conditions of wildlife-vehicle interactions and WVCs on MoDOT roads in Missouri is essential to identifying and ranking WVC sites in order to create a list of statewide wildlife crossing needs. Current conditions evaluated for the Study included a literature review of the current best practices for WVC reduction strategies and wildlife crossing structures, a review of available spatial datasets and MoDOT crash data, and a review of Missouri wildlife ecology and priority species for the Study as identified by MoDOT and the TAC. Collectively, the results from this section will be used to prioritize road segments for WVC mitigation.

2.1 Literature Review

Previous studies on WVC reduction strategies, the effectiveness of various wildlife crossing structures, and habitat connectivity plans have been conducted throughout the United States. A literature review was conducted to review relevant studies to help inform available WVC reduction strategies for this Study. Findings of the literature review are summarized in **Appendix A**.

2.2 Missouri Department of Transportation Roadways

MoDOT manages an extensive highway system and Right-of-Way (ROW) area throughout Missouri, totaling approximately 1.2 million acres and encompassing roadways, medians, shoulders, and adjacent spaces such as drainage or utility easements. MoDOT is organized into 10 subdivisions, each with specific responsibilities related to transportation planning, construction, safety, and administration (Missouri Department of Transportation [MoDOT] 2025c). **Table 2-1** is a summary of the key divisions and their respective functions:



Table 2-1: MoDOT Subdivisions

MoDOT Division	Responsibilities
Transportation Planning	Develops and manages the Five-Year Statewide Transportation Improvement Program (STIP); Oversees long-range and short-range transportation planning and policy development; Works with local agencies on transportation improvements
Highway Safety and Traffic	Focuses on roadway safety initiatives; Manages traffic incidents, work zones, and traveler information; Implements safety programs
Bridge	Oversees the inspection, maintenance, and design of bridges; Manages bridge rehabilitation and replacement projects.
Design	Implements project design guidelines and standards; Ensures compliance with environmental and engineering requirements
Construction and Materials	Oversees construction projects to ensure quality and compliance; Manages materials testing, quality control, and specifications
Maintenance	Maintains state highways and bridges; Conducts snow removal; Responsible for road maintenance, including pothole repairs and resurfacing
Motor Carrier Services	Helps commercial motor carriers get permits and credentials; Ensures compliance; Regulates commercial vehicle operations
Multimodal Operations	Supports transportation beyond highways and administers state and federal programs for aviation, railroads, transit, waterways, and freight
Audits and Investigations	Audits department operations; Investigates fraud, waste, abuse, employee grievances, and Equal Employment Opportunity complaints; Conducts mediations and analyzes competitive bidding practices
Government Relations	Acts as a liaison between MoDOT and the Missouri General Assembly, Congressional Delegation, and local political subdivisions; Develops legislation, recommends policy changes, and increases public awareness of department initiatives

Source: MoDOT 2025o.

2.2.1 MoDOT Highway System

The MoDOT highway system is divided into seven districts (MoDOT 2025j), each covering specific counties (MoDOT 2025m). **Table 2-2** below outlines each district's main office location and the number of counties and roads included in the district.



Table 2-2: MoDOT Districts

District Name	Office Location	Number of Counties Covered	Number of MoDOT Roads per District
Northwest	St. Joseph	20	1,655
Northeast	Hannibal	17	1,161
Kansas City	Lee's Summit	9	2,295
Central	Jefferson City	18	2,027
St. Louis	Chesterfield	4	2,023
Southwest	Springfield	21	2,673
Southeast	Sikeston	25	2,397

Source: MoDOT 2025j; MoDOT 2025i.

The MoDOT highway system spans 33,811 miles, ranking it as the seventh largest in the nation by highway mileage. Within this system, there are 1,385 miles of interstate highways (fifth-most nationally), 3,412 miles of U.S. routes, 8,261 miles of state routes, 18,998 miles of lettered routes, and 1,755 miles of other routes, including outer roads and business routes, all maintained by MoDOT (MoDOT 2022a).

Seven interstates cross through Missouri (TRIP 2006). Sections of Interstate 70, Interstate 35, and Interstate 44 can exceed 100,000 vehicles per day. Minor routes, including state highways (SH) and lettered routes, typically carry fewer vehicles, with annual average daily traffic (AADT) in the low thousands, particularly in rural areas. The lowest volumes are found on rural roads where AADT can be under 1,000 vehicles, better suited for local traffic rather than through-travel.

Table 2-3: MoDOT Maintained Routes

Routes	Mileage	Statewide AADT (vehicles per day)
Interstates	1,385	62,000
U.S. Routes	3,412	22,000
State Routes	8,261	8,000
Lettered Routes	18,998	1,800
Other	1,755	888
Total	33,811	94,688

Source: MoDOT 2022a; MoDOT 2022c.

Traffic distribution varies significantly across MoDOT routes. Major routes (totaling 5,555 miles) carry approximately 77 percent of all traffic. Minor routes, covering 18,114 miles, handle about 22 percent of traffic, while low-volume routes (totaling 10,142 miles) account for just 1 percent of traffic (MoDOT 2022a; MoDOT 2022b), as seen in **Table 2-4** below.



Table 2-4: Traffic Distribution on MoDOT Maintained Routes

Routes	Mileage	Percentage of Traffic
Major Routes	5,555	77%
Minor Routes	18,114	22%
Low-Volume Routes	10,142	1%
Total	33,811	100%

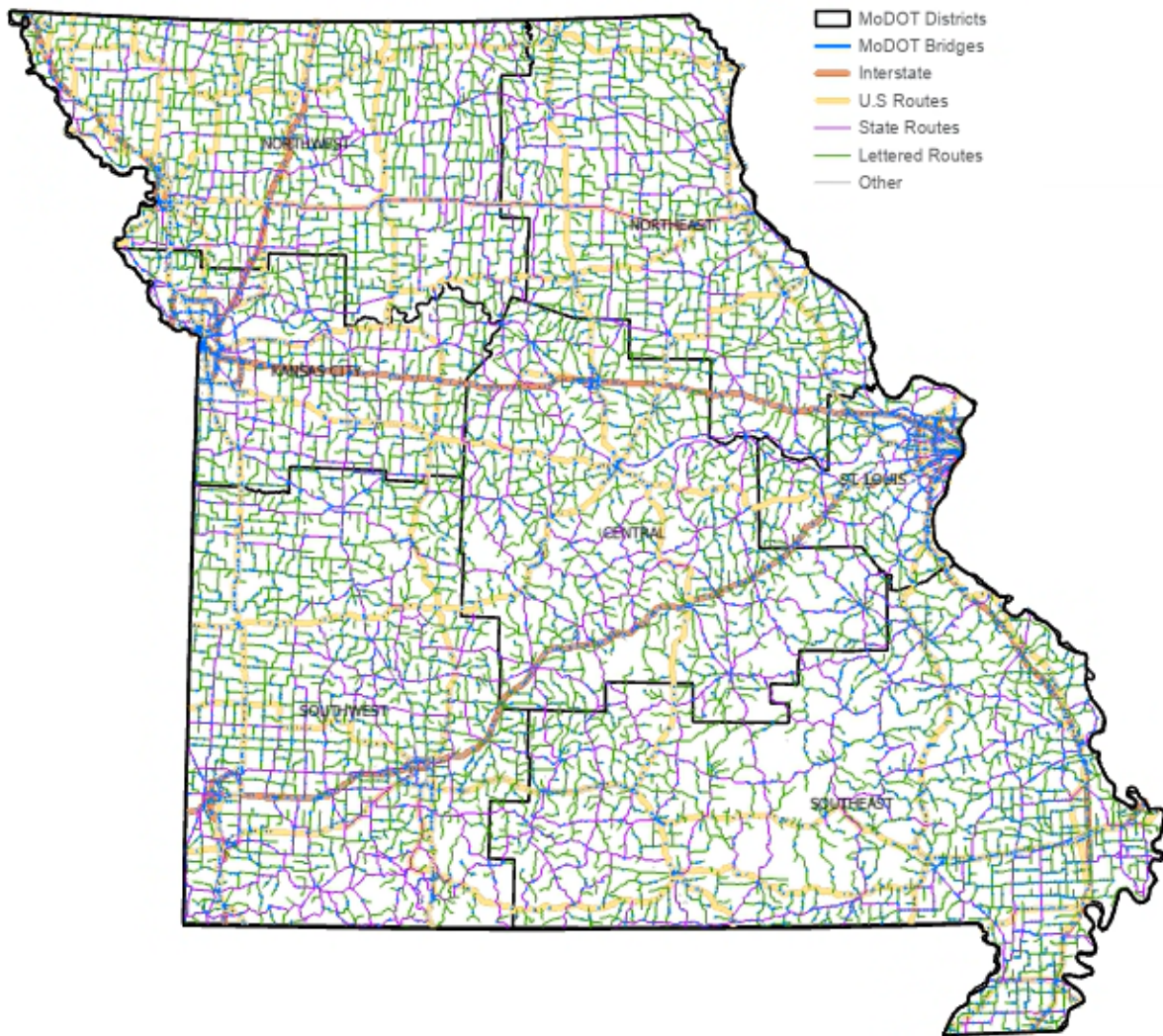
Source: MoDOT 2022a.

In addition to maintaining roads and ROW, MoDOT also oversees 3,185 culverts and 7,269 bridges throughout the state. An estimated 209 bridges are more than 1,000 feet in length (MoDOT 2022a). Geospatial data containing the locations of and details for MoDOT culverts and bridges was obtained from MoDOT for this Study. **Table 2-5** below outlines the number and mileage of the structures.

Table 2-5: MoDOT Bridges and Culverts

Routes	Number of Structures	Mileage
Culverts		
Major	717	5
Minor	2,468	14
Bridges		
Major	2,893	185
Minor	4,376	166
Total	10,454	370

Figure 2-1: MoDOT Districts and Roads



2.3 Wildlife Vehicle Collision Hot Spot Analysis

Information on MoDOT roadways was combined with previously collected data detailing WVCs and carcasses to identify locations where WVCs frequently and regularly occur in Missouri, hereafter referred to as “hot spots.” A WVC hot spot analysis was conducted to identify and rank WVC hot spots and meet the Study’s objectives.

2.3.1 Wildlife Vehicle Collision Datasets

Several datasets were reviewed to determine their suitability for inclusion in the hot spot analysis, including information on reported crashes involving wildlife, and notifications of wildlife carcasses within MoDOT roadways or ROWs.

2.3.1.1 MISSOURI STATE HIGHWAY PATROL CRASH DATA

The primary source and largest dataset for WVCs in Missouri is the Missouri Crash Analysis Reporting System (MOCARS), maintained by the MSHP. The MSHP documents reported or



discovered crashes on MoDOT roads. Data recorded for each crash includes the crash coordinates, type of crash, severity ranking, time of crash, and other related characteristics. The crash type includes several categories, but for this study we were interested in the categories “Deer” and “All Other Animals Not Farm Animal, Dog, or Domestic”, which effectively filters the dataset to only wildlife-related crashes. The MSHP dataset served as the primary WVC dataset for this Study because of its statewide and standardized collection system, which resulted in increased reliability of the data.

To better understand both short and long-term crash trends for this Study, the filtered MSHP crash data was then summarized for both the last 5 (2019-2023) and 10 years (2014-2023). A total of 17,654 WVCs were recorded in the 5-year dataset, and a total of 33,272 WVCs were recorded in the 10-year dataset. **Table 2-6** below outlines crash characteristics for WVC crashes occurring over the previous 5 and 10 years.

Table 2-6: MSHP 5 and 10-Year Crash Data

Crash Details	5-Year Crash Data (2019-2023)		10-Year Crash Data (2014-2023)	
	Crash Count	Percent Total	Crash Count	Percent Total
Animal Type				
Deer	16,855	95%	31,858	96%
Not Deer	799	5%	1,475	4%
Lighting Type				
Daylight	4,676	26%	8,394	25%
Dark with Street Lights Off	11,888	67%	22,683	68%
Dark with Street Lights On	939	5%	1,940	6%
Dark - Unknown	126	1%	250	1%
Not Stated / Unknown	25	Less than 1%	66	Less than 1%
Weather				
Clear	12,750	72%	23,551	71%
Cloudy	3,984	23%	7,796	23%
Rain	486	3%	978	3%
Fog / Mist	234	1%	541	2%
Snow / Sleet	45	Less than 1%	75	0.2%
Other / Unknown	53	Less than 1%	174	1%
Quarters				
Q1 (January-March)	2,929	17%	5,374	16%
Q2 (April-June)	3,798	22%	7,153	21%
Q3 (July-September)	2,501	14%	4,507	14%
Q4 (October-December)	8,426	48%	16,299	49%
Rural-Urban				
Urban	1,412	8%	2,743	8%



Missouri Statewide Wildlife Vehicle Collision Study Current Conditions

Crash Details	5-Year Crash Data (2019-2023)		10-Year Crash Data (2014-2023)	
	Crash Count	Percent Total	Crash Count	Percent Total
Rural	13,189	75%	24,505	74%
Urbanized	3,053	17%	6,084	18%
Road Surface				
Dry	16,055	91%	30,205	91%
Wet	1,520	9%	2,960	9%
Ice / Snow / Slush / Unk	79	Less than 1%	75	Less than 1%
Severity				
Fatal	22	Less than 1%	43	Less than 1%
Suspected Serious Injury	173	1%	175	1%
Suspected Minor Injury	8	Less than 1%	8	Less than 1%
Minor Injury	1,450	8%	2,610	8%
Property Damage Only	16,008	91%	30,381	91%
Disabling	0	0%	116	Less than 1%
Functional Class				
Freeway	5,755	33%	7,955	24%
Interstate	4,504	26%	5,530	17%
Major Collector	2,644	15%	6,316	19%
Minor Collector	495	3%	726	2%
Principle Arterial	2,307	13%	6,208	19%
Minor Arterial	1,661	9%	6,178	19%
Not Stated	134	Less than 1%	134	Less than 1%
MoDOT District				
Central	3,293	19%	6,369	19%
Kansas City	2,627	15%	5,060	15%
Northeast	2,370	13%	4,309	13%
Northwest	1,424	8%	2,406	7%
Southeast	2,951	17%	5,905	18%
St. Louis	2,493	14%	4,781	14%
Southwest	2,496	14%	4,503	14%
Posted Speed Limits				
10-25 mph	17	Less than 1%	42	Less than 1%
30-40 mph	649	4%	1,132	3%
45-55 mph	6,212	35%	14,672	44%
60-70 mph	10,495	59%	17,099	51%
Not Stated	281	1%	410	1%

The 10-year dataset recorded 43 fatalities and 2,610 minor injuries to motorists involved in WVCs. These numbers are roughly cut in half within the 5-year dataset, which included 22 fatalities and



1,450 injuries. A disproportionate number of fatalities (72 percent) and serious injuries (72 percent) involved motorcyclists. Other notable trends between the 5- and 10-year WVC datasets included:

- 95 percent of all WVCs were deer related.
- More than 50 percent of WVCs occurred in dark conditions with no street lighting.
- Approximately half of WVCs occurred between October and December.
- Approximately 75 percent of WVCs were in rural areas.
- 95 percent of all WVCs occurred in areas with a posted speed limit of 45 mph or greater.

Variations between the two datasets were minor, and generally the above trends were within five percentage points of each other.

2.3.1.2 CARCASS DATA

Another data source commonly used to aid understanding of WVCs are records of wildlife carcasses found within the road or ROW. Carcass data is an important element in understanding WVCs as it often provides information on collisions involving medium and small-bodied wildlife that typically do not cause vehicle damage upon impact and thus may not be otherwise reported. The State of Missouri has no uniform carcass data recording system, however three datasets containing wildlife carcass information were identified and reviewed for potential inclusion in the Study. These datasets included the MoDOT Customer Service Calls database, the iNaturalist GLOBAL Roadkill Observations database, and carcass data within MDC Natural Heritage data.

2.3.1.3 MODOT CUSTOMER SERVICE

MoDOT provides a customer service telephone hotline and online form for motorists to notify MoDOT of road-related concerns or issues, including wildlife carcasses. Calls and form submissions to MoDOT Customer Service are documented by topic and can be filtered to show only animal carcass removal requests. MoDOT maintenance staff respond to these notifications and record general comments about the removal, geographic coordinates, and information about the type of animal removed. Records from the MoDOT Customer Service dataset are considered independent from the MSHP crash dataset and therefore were analyzed separately for the Study due to differences in data collection methodology: the MSHP removes the carcass from the roadway after responding to a call, while MoDOT maintenance staff remove carcasses at the time of response.

Customer service data was obtained for 2015-2023 and filtered to exclude all domestic animals. The final wildlife carcass removal dataset contained 5,992 records. The majority of the records involved one animal, but less than 1 percent pertained to multiple animals. The species and number of carcasses removed reported between 2015-2023 are summarized in **Table 2-7** below.

Table 2-7: MoDOT Customer Service Wildlife Carcass Removal Calls

Species Common Name	Number of Reported Carcasses
White-Tailed Deer	4,996
Unknown	761
Raccoon	112
Coyote	42
Skunk species	33
Fox species	14
Nine-Banded Armadillo	13
Virginia Opossum	9
Goose species	7
Wild Turkey	7
American Black Bear	2
American Beaver	2
Bird species	2
Bobcat	2
American Badger	1
Eagle species	1
Squirrel species	1
Turtle species	1
Wild Pig (feral hog)	1
Total	5,992

The dataset showed a high proportion of reported deer carcasses when compared to all other wildlife, likely due to their larger body size causing a potential impediment to traffic. Reports of other species commonly found throughout Missouri and frequently involved in WVCs, such as squirrels, racoons, opossums, and armadillos, appear to be underreported within the dataset. Within the dataset, carcass reporting occurs most frequently within urban areas and/or along major roads and highways. Due to the reporting biases observed within the dataset (larger carcasses reported more frequently and carcasses in urban areas more likely to be reported), the significance of the dataset and any conclusions drawn from it are reduced.

iNaturalist GLOBAL Roadkill Observations

The iNaturalist GLOBAL Roadkill Observations dataset is a citizen science survey effort to record incidental carcass observations throughout the world in order to help inform governments and organizations of locations where WVCs are occurring (iNaturalist 2017). Reports of WVCs submitted to the survey include information on the species, location, and evidence of the incident, such as photos. The GLOBAL Roadkill dataset obtained for Missouri contains 344 records; however, only six of the records contained target species for the Study, consisting of three white-tailed deer and three American badger occurrences. The records were collected between 2019 and 2022 across six counties. Although records within this dataset are reviewed by the community for accuracy, the incidental nature of the data collection, as well as the lack of target species records, make the dataset of minimal analytical benefit for this Study.



MDC Natural Heritage Data

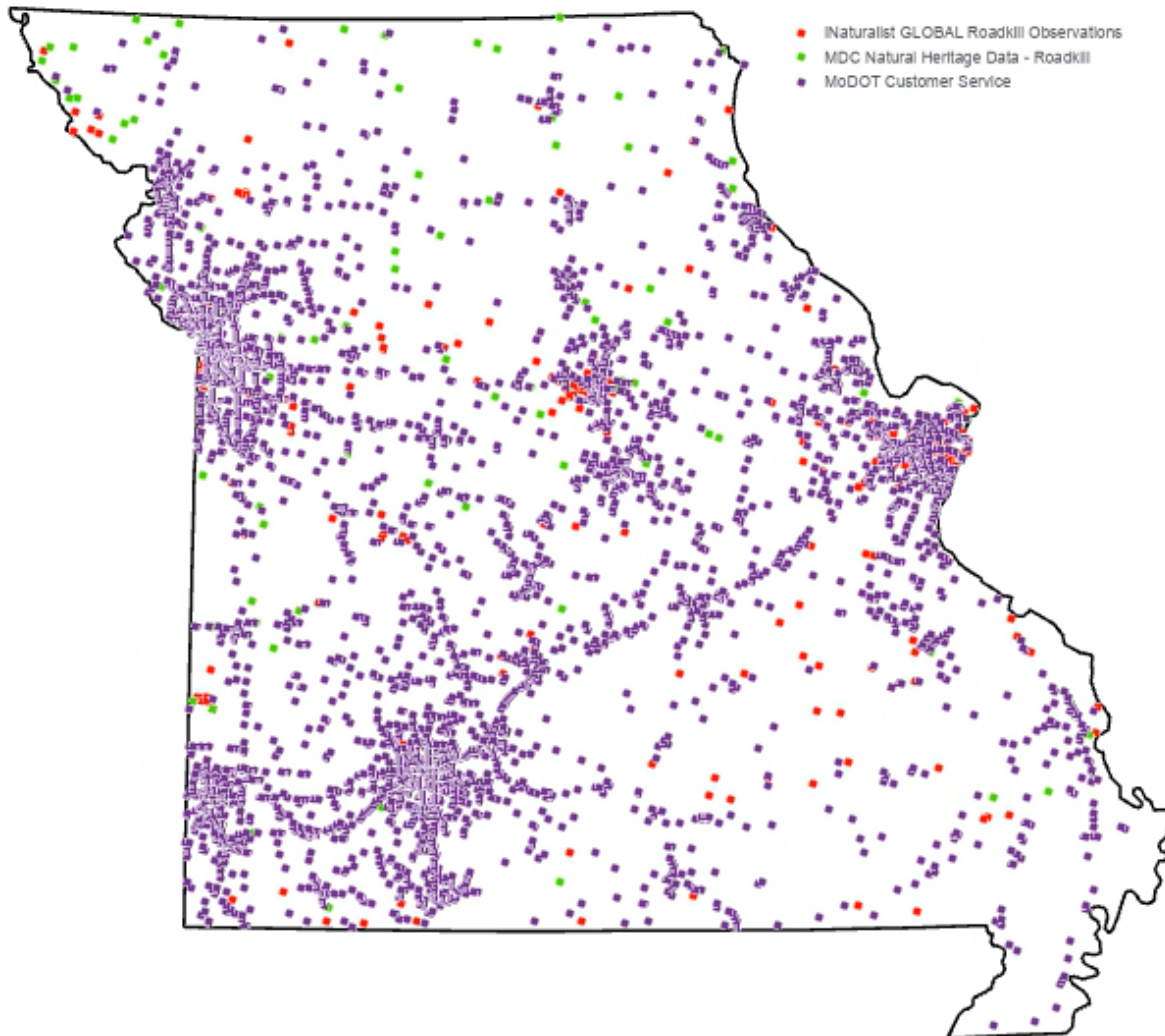
MDC Natural Heritage carcass data, part of the larger MDC Natural Heritage occurrence record dataset, was also reviewed for potential use in the WVC hot spot analysis. The MDC Natural Heritage carcass dataset contains 96 records for 11 of the Study's target species, as shown in **Table 2-8**. The records were collected between 1984 and 2022.

Table 2-8: MDC Natural Heritage Carcass Data for Target Species

Target Species Common Name	Species Scientific Name	Number of Records
American Badger	<i>Taxidea taxus</i>	71
Bald Eagle	<i>Haliaeetus leucocephalus</i>	1
Black-Tailed Jackrabbit	<i>Lepus californicus</i>	1
Franklin's Ground Squirrel	<i>Poliocitellus franklinii</i>	7
Great Plains Toad	<i>Anaxyrus cognatus</i>	3
Indiana Bat	<i>Myotis sodalis</i>	1
Least Weasel	<i>Mustela nivalis</i>	1
Long-Tailed Weasel	<i>Mustela frenata</i>	5
Plains Spotted Skunk	<i>Spilogale putorius</i>	4
Western Foxsnake	<i>Pantherophis ramspotti</i>	1
Western Mudsnake	<i>Farancia abacura</i>	1

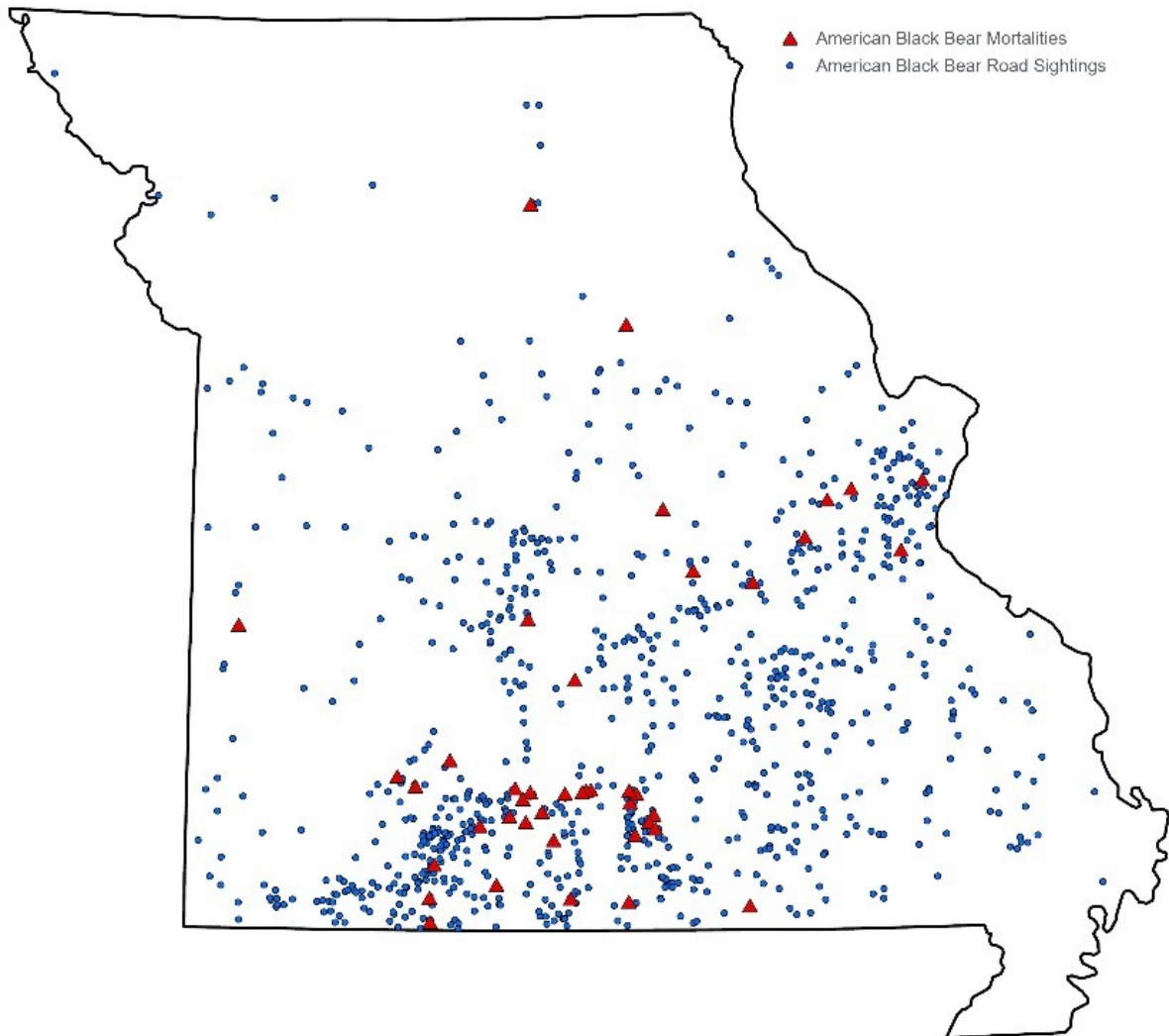
A map of the various carcass datasets is illustrated in **Figure 2-2** below.

Figure 2-2: Carcass Data



MDC also maintains a database of American black bear (*Ursus americanus*) collision data and sightings (**Figure 2-3**). The data set contains 60 records of American black bear mortalities due to WVCs in Missouri, collected between 2011 and 2024. The collisions primarily occurred in the southwest portion of the state, with a few along Interstate 44 near St. Louis. Both the MDC carcass data and the American black bear collision data are collected on an incidental basis, relying heavily on motorist reports to populate the dataset.

Figure 2-3: American Black Bear Collision and Road Sightings Data



Due to the lack of standardized methodology to systematically collect carcass data, it was determined that any analysis utilizing the above datasets would not provide reliable results. These datasets, therefore, were not used in the WVC hot spot analysis.

2.3.2 Methodology

Different methods may be used for the WVC hot spot analysis depending on the overall goals of the study. This Study employed ESRI's Optimized Hot Spot Analysis (OHSA) tool, a method regularly used to conduct WVC hot spot analyses across large spatial scales (Cramer and McGinty 2018; Garrah et al. 2015; Shilling and Waetjen 2015). OHSA uses the Getis-Ord G_i^* statistic, a process by which parameters derived from the input data characteristics are used to produce optimized results. The resulting output details spatially significant spatial clusters of WVCs and identifies hot and cold spots (ESRI, n.d.). In consultation with the TAC, the following methodology was employed to analyze the MSHP crash data.

The OHSA evaluates points within polygons to find where there are greater numbers of points than expected along a road. The polygons are created by the user and are typically representative in this type of modeling of one-half or one mile road segments. The hot spots are based on the crashes per polygon rate and its neighbors; the greater the number of crashes above what would be statistically expected, the higher the model has in its confidence in the hot spot, ranking them as being within 90, 95 or 99 percent Confidence Intervals. The preparation of the roads layer polygon and the crash data that are combined for the hot spot analysis are summarized in **Table 2-9** below, and described in detail in **Appendix B**.

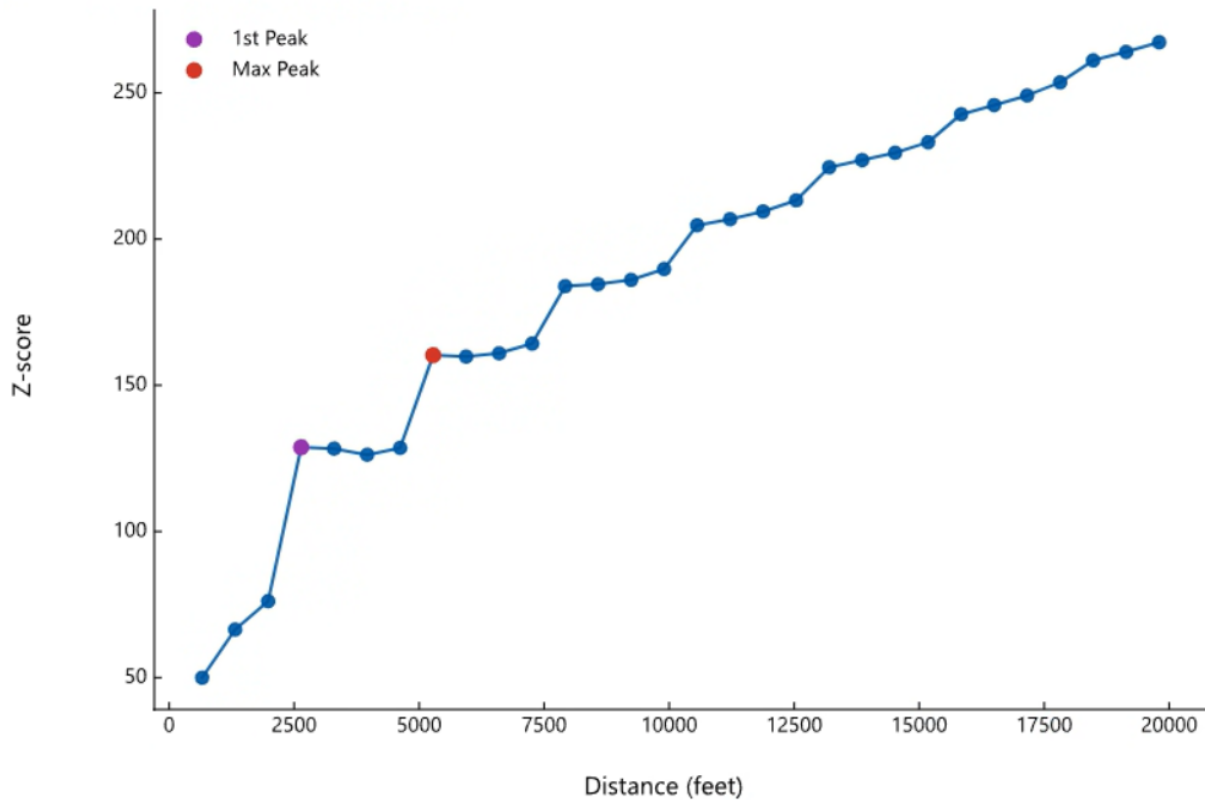
Table 2-9: Optimized Hot Spot Analysis Roads Polygon Creation Steps

Step	Geoprocessing Tool(s)	Description
1	Buffer, Polygon to Centerline	Buffer the MoDOT Operated Roads centerline by 660 feet either side and dissolve by travel way name (i.e. 70, 64, DD) to combine ramps, divided highways, and other complex road networks within the same route. Dissolving by travel way name prevented intersections from becoming conglomerates that were difficult to segment evenly across the entire state. The polygon to centerline tool created a new simplified centerline.
2	Generate Points Along Line, Split Line at Points	The simplified centerline was split into 0.5-mile segments to ensure fine scale analysis.
3	Buffer	The 0.5-mile segments were buffered by 660 feet to ensure that all WVC incidents and future prioritization datasets were captured. This created a 0.5-mile by 0.25-mile polygon (segment).

An important note regarding the roads polygon creation is the overlap of segments at intersections and areas where multiple travel ways utilize the same alignment. Given the large number of roads, it was not feasible to manually edit and remove these overlapping segments, which account for both intersections and colinear travel ways. Furthermore, the polygon did have segments which were less than a 0.5-mile because road centerlines were not rounded to 0.5-mile increments and there was always a remainder. The resulting polygon consisted of 68,912 segments. Despite these known flaws, overlapping and small segments were determined to not skew the results from the OHSA or prioritization results since each 0.5-mile segment is evaluated individually and later merged together.

The OHSA compares the number of incidents within each segment polygon to its nearest neighbors to determine significant hot or cold spots with varying confidence intervals. The OHSA automatically calculates a distance band (search distance out toward neighbors) based on input parameters, however, users of the tool can override this with a distance band more appropriate to the data and overall study objectives. The greater the distance band, the longer the hot spots, while the shorter the distance band, the shorter the hot spots and the greater number of hot spots. A balance has to be achieved for each study. Spatial autocorrelation is a geoprocessing tool that can help identify a suitable distance band where significant clustering occurs. The tool outputs a z-score for each distance band tested, and statistically significant peak z-scores indicate distances where spatial processes promoting clustering are most pronounced. The tool was run for 30 iterations at a 660-foot (1/8th-mile) interval, and results showed the first peak to occur at 0.5 mile (**Figure 2-4**).

Figure 2-4: Spatial Autocorrelation Results for the 2019-2023 WVC Crash Data.



To provide further information, the OHSA was computed for the half, one, two, three, four, and five-mile distance bands across both the five and ten-year datasets. The OHSA analysis results assign z-scores to each 0.5-mile segment, and those segments that are considered a significant hot spot are binned into three confidence intervals – 90 percent, 95 percent, and 99 percent - which represents the level confidence that percentage of the dataset falls within a variance of the average.

2.3.3 Results

Across the various distance bands and temporal datasets, the OHSA identified between 4,367 to 16,974 significant hot spots. The percentage of hot spots over all 68,912 0.5-mile segments were generally within two percentage points of one another. Significant cold spots were only present at the 3-mile distance band and greater. Across all distance bands, more than 70 percent of the hot spots had a 99 percent confidence interval. The OHSA results across the five distance bands are outlined in the table below and shown in **Appendix C**.



Table 2-10: Five and Ten-year Optimized Hot Spot Analysis Results for WVCs Across Various Distance Bands.

	Cold Spot Segment Count Confidence Intervals				Hot Spot Segment Count Confidence Intervals				Percentage of 99% Hot Spots / All Segments	Percentage of All Hot Spots / All Segments
	5-year Dataset									
Distance Band	90%	95%	99%	Total	90%	95%	99%	Total		
0.5-mile	0	0	0	0	998	189	3,180	4,367	5%	6%
1-mile	0	0	0	0	464	1,127	4,394	5,985	6%	9%
2-mile	38	0	0	38	902	1,354	6,572	8,828	10%	13%
3-mile	669	186	21	876	971	1,546	8,760	11,277	13%	16%
4-mile	12,011	7,599	235	19,845	1,780	2,165	10,415	14,360	15%	21%
5-mile	5,904	15,605	6,088	27,597	1,343	2,471	12,098	15,912	18%	23%
	10-year Dataset									
0.5-mile	0	0	0	0	374	1,057	3,389	4,820	5%	7%
1-mile	0	0	0	0	628	1,190	5,289	7,107	8%	10%
2-mile	40	0	0	40	546	1,384	8,110	10,040	12%	15%
3-mile	5,931	717	34	6,682	1,267	1,518	10,223	13,008	15%	19%
4-mile	7,567	18,024	1,640	27,231	1,328	2,537	11,731	15,596	17%	23%
5-mile	4,014	11,274	16,407	31,695	1,184	2,276	13,514	16,974	20%	25%

Results from the above analyses were reviewed with the TAC, and the following values were determined ideal and carried forward in the crash map used in the Study (**Table 2-11**).

Table 2-11: Optimized Hot Spot Analysis Variables and Set Values.

Variable	Set Value	Reasoning
Road Segment Length	0.5-mile	1-mile road segments resulted in fragmented hot spots when there was a road intersection or the road came to a state boundary. The 0.5-half mile segments were able to absorb smaller fragments of segments near intersections and boundaries and remain "intact" rather than become fragmented. The 0.5-mile road segments helped to ensure fine scale analyses.
Buffer distance	660 feet (0.125-mile)	This is the distance the model reaches out from that center line first created earlier, to represent the road outward in both directions. This results in road segments with the width of quarter mile.
Distance Band	0.5-mile	This helps the model results be more accurate. 0.5-mile distance band was used in the Study because of their granularity and reduction in the overall number of hot spots which helps to prioritize an extensive road system. Increasing the distance band beyond a mile made it difficult to dissect the intricacies of complex road networks with high traffic volumes, primarily centered around the urban environment.
Years of Crash Data	5-year	There was modeling of 10 years of data (2014-2023), however, to best represent what had happened more recently after several wildlife mitigation projects, COVID-19 pandemic changes, landscape and wildlife populations changes, and to be in line with how traffic safety engineers examine crash data for the most recent five years, these last five years of crash data were used.
Confidence Intervals	99%	Confidence intervals display how confident the model results are to be accurate and statistically significant. The 95% and 99% confidence intervals were chosen. The model runs of half mile road segments and half mile distance bands selected as the most appropriate road segment size included most 90% confidence interval areas without having to instruct the model to include these. Thus only 95% and 99% Confidence Intervals were included in the hot spots.

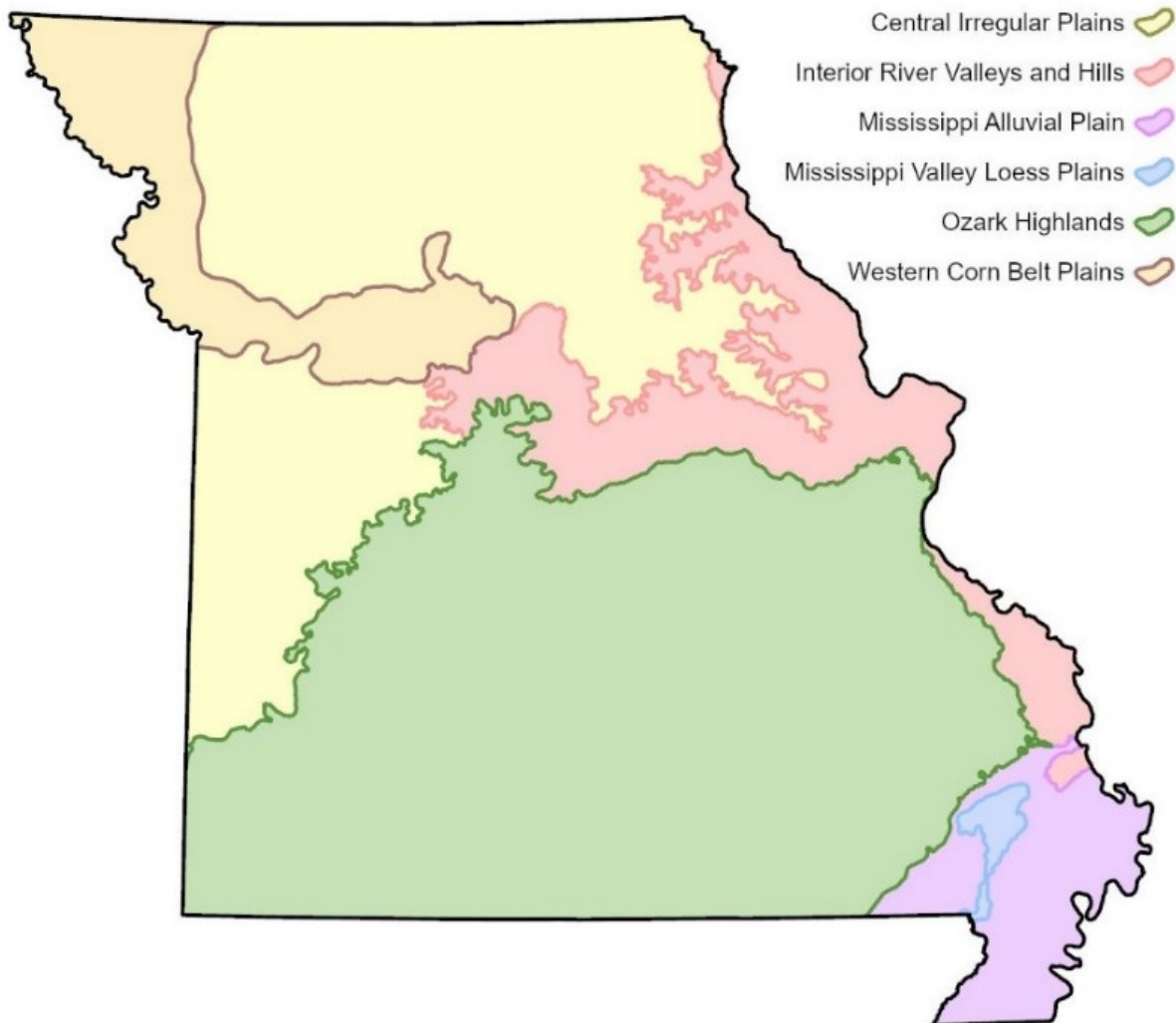
2.4 Missouri Habitat Blocks and Linkage Zones

Following the completion of the hot spot analysis, a review of Missouri wildlife ecology, wildlife habitat blocks and linkage zones, and the related available geospatial datasets was conducted to identify and include ecological data in the subsequent prioritization.

2.4.1 Missouri Ecology

Ecological regions, or ecoregions, are used to group large areas of land containing similar characteristics, such as geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. Throughout the United States, ecoregions have been defined at both broad and small scales within each state. The state of Missouri is divided into six broad-scale ecoregions (Chapman et al. 2002), displayed in the figure below.

Figure 2-5: Missouri Ecoregions



Central Irregular Plains

The Central Irregular Plains ecoregion covers most of the northern half of Missouri and is made up of glaciated grasslands and woodlands, with forested riparian zones to the north and flat to rolling hill topography to the south. Coal mining was historically common throughout the ecoregion and continues in a few locations today.

Interior River Valleys and Hills

This ecoregion follows the Missouri and Mississippi River corridors from the central portions to eastern edge of Missouri. The topography of the ecoregion consists of wide valleys and dissected glacial-till plains that lie between the Ozarks to the south and plains to the north. Land use in these areas is predominantly cropland, with pasture and forest interspersed.

Mississippi Alluvial Plain

The Mississippi Alluvial Plain ecoregion is found in the bootheel of Missouri and consists of alluvial plains interspersed with river terraces and levees. Stretching from southern Illinois to the Gulf of Mexico, the portion of this ecoregion in Missouri represents the northernmost range for many



coastal plain species. Soils are poorly drained, although many areas have been drained and cleared for crop production.

Mississippi Valley Loess Plains

The Mississippi Valley Loess Plains covers a small area in the southeastern corner of Missouri. Topography in this ecoregion consists of plains and low hills. Land use is primarily pasture and oak-hickory-pine forests, and soils are well drained and prone to erosion.

Ozark Highlands

The Ozark Highlands ecoregion covers most of the southern half of Missouri and is characterized by large, forested tracts of land interspersed with small, cultivated areas in valleys and bottomlands. Pastures are commonly found in cleared upland areas. Topography throughout the ecoregion ranges from moderate rolling hills along plateaus and upland areas, to steep slopes in riparian zones. Bedrock throughout the ecoregion is primarily made up of Cambrian and Ordovician dolomite and sandstone, and Mississippian limestone. Karst features are common and scattered throughout the ecoregion.

Western Corn Belt Plains

The Western Corn Belt Plains ecoregion is found in the far northwestern corner of Missouri. This ecoregion historically consisted of tallgrass prairie but has largely been converted to agriculture and pasture. Topography in this area is made up of level to hilly plains.

2.4.1.1 LANDCOVER

Each ecoregion contains predominant landcover types, which can be used to identify habitat blocks (discrete areas of habitat) and linkage zones (areas of habitat connectivity) for Missouri wildlife species. Land cover data for the Project was obtained from the 2021 USGS Land Use Land Cover (LULC) raster dataset (United States Geological Survey [USGS] 2023b) and from the MDC Natural Heritage occurrence record dataset, which included information on the location of unique natural communities throughout Missouri. The USGS LULC dataset divides land cover in Missouri into 15 categories, as described in **Table 2-12**.

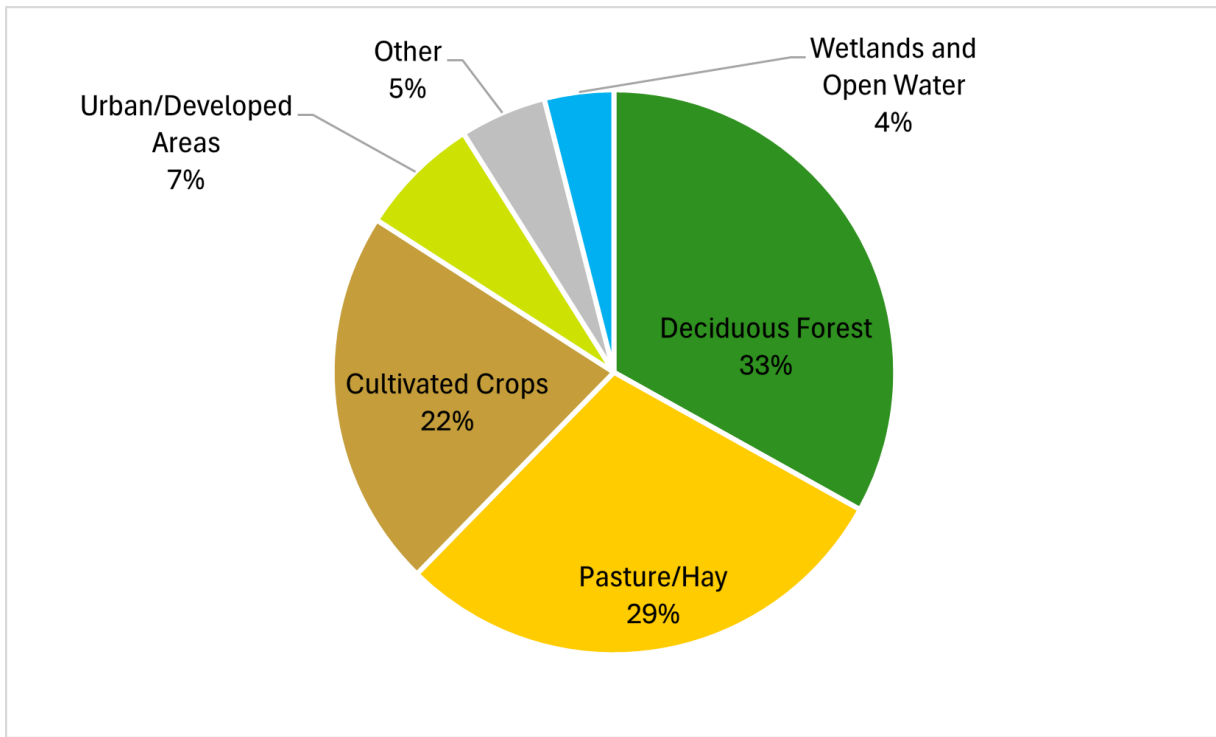
Table 2-12: Land Cover Types in Missouri

Land Cover Type	Description
Open Water	Areas of open water with less than 25% cover of vegetation or soil.
Developed, Open Space	Areas with constructed materials and vegetation in the form of lawn grasses with less than 20% cover by impervious surfaces.
Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation with 20% to 49% cover by impervious surfaces.
Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation with 50% to 79% cover by impervious surfaces.
Developed, High Intensity	Highly developed areas with 80% to 100% cover by impervious surfaces.
Barren Land	Areas of bedrock, talus, glacial debris, strip mines, gravel pits, and other accumulations of earthen material where vegetation accounts for less than 15% of total cover.
Deciduous Forest	Areas where tree cover is greater than 20% of total vegetative cover and more than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas where tree cover is greater than 20% of total vegetation cover and more than 75% of the tree species maintain their leaves all year.
Mixed Forest	Areas where tree cover is greater than 20% of total vegetation cover and neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrub/Scrub	Areas dominated by shrubs less than 16 feet tall with shrub canopy typically greater than 20% of total vegetation and including true shrubs, young trees in early successional stage, or trees stunted from environmental conditions.
Grassland/Herbaceous	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Cultivated Crops	Areas used for the production of annual crops and perennial woody crops, as well as land being actively tilled. Crop vegetation accounts for greater than 20% of total vegetation.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Source: USGS 2023b

Statewide, the dominant land cover types in Missouri consist of agricultural land (including both hay/pasture and cultivated crops) and deciduous forests. Other, less dominant, land cover types throughout the state include urban and developed areas, wetlands, and open water (found mainly along major rivers such as the Missouri and Mississippi). The figure below shows the distribution of land cover types throughout the state.

Figure 2-6: Percentage Distribution of Missouri's Land Cover Types



Source: USGS 2023b

Land use and land cover are influenced by ecoregion characteristics, resulting in uneven distributions throughout the state. **Table 2-13** shows land cover percentages within each Missouri ecoregion.

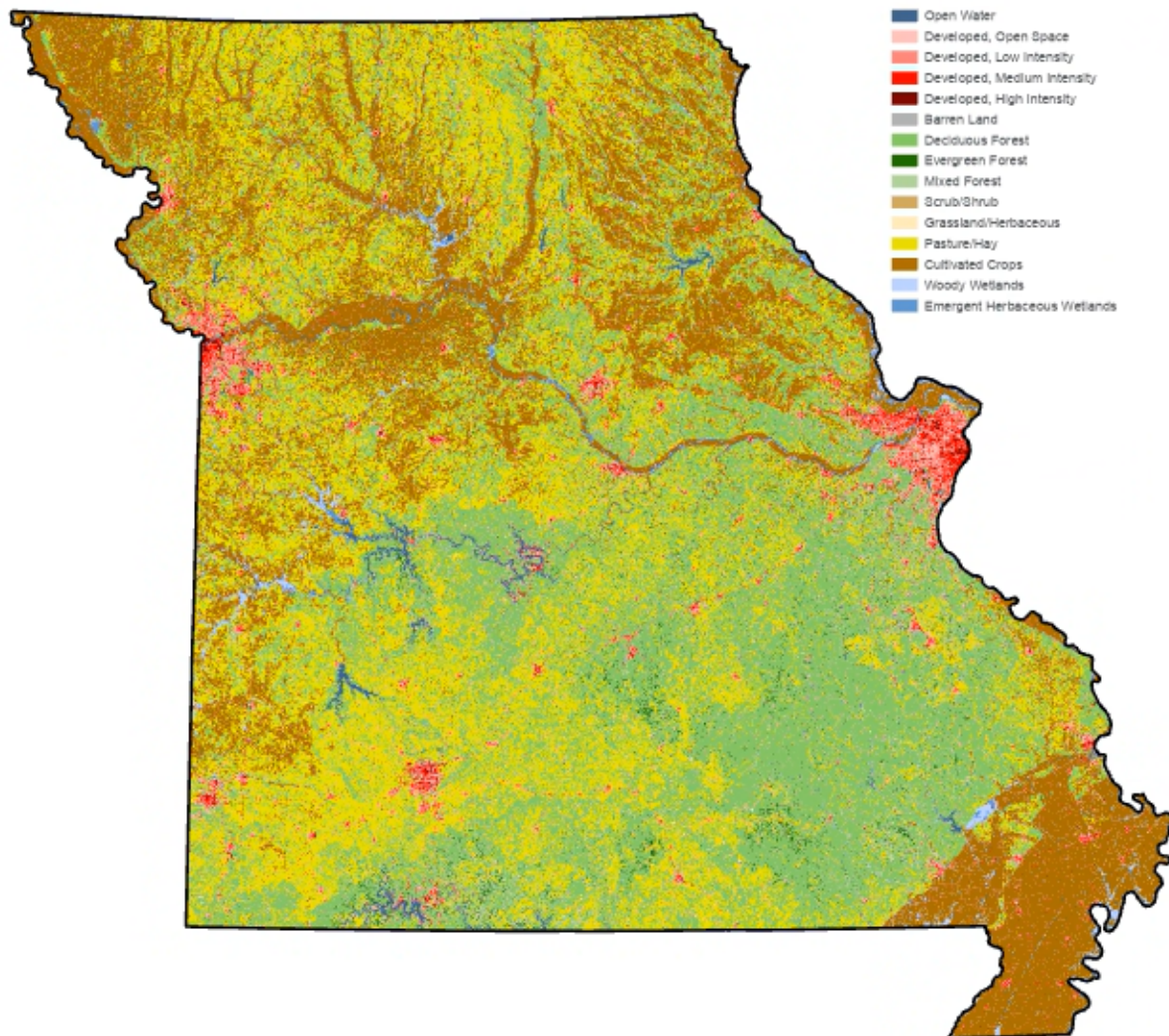


Table 2-13: Percentage of Land Cover Distribution in Missouri Ecoregions

Land Cover Type	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
Open Water	0.8%	2.7%	1.7%	0.5%	1.2%	1.4%
Developed Open Space	3.6%	5.4%	2.3%	4.5%	4.5%	3.7%
Developed Low Intensity	2.5%	4.8%	3.5%	2.2%	1.6%	4.0%
Developed Medium Intensity	0.7%	2.9%	0.7%	0.6%	0.7%	1.6%
Developed, High Intensity	0.2%	0.8%	0.1%	0.1%	0.1%	0.5%
Barren Land	0.1%	0.4%	0.1%	0.2%	0.3%	0.2%
Deciduous Forest	16.7%	32.0%	0.7%	13.7%	50.9%	10.7%
Evergreen Forest	0.1%	0.5%	<0.1%	<0.1%	1.7%	<0.1%
Mixed Forest	0.2%	1.3%	<0.1%	0.6%	3.5%	<0.1%
Shrub/Scrub	0.3%	0.1%	<0.1%	<0.1%	0.2%	0.1%
Herbaceous	0.4%	0.3%	<0.1%	0.2%	0.7%	0.3%
Hay/Pasture	38.7%	24.3%	0.7%	19.8%	31.8%	17.7%
Cultivated Crops	32.8%	21.4%	83.7%	34.1%	2.2%	56.4%
Woody Wetlands	2.5%	2.4%	5.9%	2.5%	0.3%	1.8%
Emergent Herbaceous Wetlands	0.4%	0.9%	0.6%	0.2%	0.1%	1.2%

Source: USGS 2023b.

Figure 2-7: Land Cover in Missouri



2.4.2 Missouri Habitat Blocks

The characteristics and usage of land surrounding MoDOT maintained roads have a direct influence on the frequency of vehicle-wildlife conflicts. When added to the results of the hot spot analysis, the identification of habitat blocks and linkage zones adjacent to roadways helps to further determine current and potential high-conflict areas.

In order to identify habitat blocks adjacent to MoDOT roadways, Missouri ecoregions were subdivided into discrete natural communities. Each natural community has distinct compositions and can be categorized by their defining features and predominant land cover types. For this Study, MDC natural community characterizations were used to define habitat blocks within Missouri.

Prairies, Savannas, and Altered Grasslands

Broadly referred to as grasslands, grassy, open areas in Missouri can be further categorized as prairies, savannas, or altered grasslands.

Prairie plant communities predominantly contain perennial grasses and forbs. Missouri prairies are considered tallgrass prairies, due to dominant grass species reaching heights of more than 6 feet. Twelve types of tallgrass prairies are found in Missouri, categorized based on soil types, soil moisture, and their position within the landscape (Missouri Department of Conservation [MDC] 2024h).

Savannas are considered a transition zone between prairies and forest, containing both prairie plants and scattered mature trees throughout. Minimal areas of savanna remain in Missouri; historically, however, six types of savannas were present in the state, classified by soil moisture and substrate materials (MDC 2024k). For the purposes of this Study, shrublands and other transitional areas between grasslands and forests were also considered savannas.

Altered grasslands are former prairies and savannas that have been influenced by human activities. These grasslands include pastures and old fields, as well as railroad and roadway ROWs. Plant communities in altered grasslands typically contain a mixture of native and non-native species and often have reduced habitat and ecosystem functioning when compared to undisturbed prairies or savannas (MDC 2024f).

USGS LULC data was used to represent land cover from this group of natural communities and included scrub/shrubland, herbaceous land covers, and lands used for hay/pasture.

Forests and Woodlands

Forest and woodland habitats within Missouri are dominated by trees with variable amounts of canopy closure. Forested areas typically contain a thick canopy and midstory, with a sparse understory. Canopies and midstories in woodlands are less dense than in forests, allowing for enhanced understory growth due to better light conditions (MDC 2024d). USGS LULC data was used to represent land cover from this group of natural communities and included deciduous, evergreen, and mixed forests.

Glades

Glades are hot, dry, bare, rocky areas typically found within upland woodlands. Glades are characterized by thin soils, exposed rock, minimal tree cover, and high elevations within the landscape (MDC 2024e).

Glade land cover data was obtained from the MDC Natural Heritage occurrence record dataset. Glades make up 18,170 acres in Missouri (less than 0.1 percent of the state's total land area). Glades are primarily found in the Ozark Highlands ecoregion, with a few occurring in the Central Irregular Plains and Interior River Valleys and Hills.

Cliffs and Talus

Cliffs in Missouri can reach heights of over 550 feet and are defined as "steep to vertical exposures of bedrock (or loess) 10 feet or more in height" (MDC 2024c). Cliff types are categorized by rock type and moisture, which influence the composition of natural communities (MDC 2024c).

Cliff land cover data was obtained from the MDC Natural Heritage occurrence record dataset. Cliffs make up 1,617 acres in Missouri (less than 0.1 percent of the state's total land area) and



primarily occur in the southern half of the state. Most cliffs are found in the Ozark Highlands ecoregion, with a few occurring in the Central Irregular Plains and Interior River Valleys and Hills. Talus habitats are characterized by loose rocky debris found on slopes beneath cliffs. These habitats have minimal soil and vegetation, and tree establishment is uncommon due to the lack of solid substrate (MDC 2024m). None of the MoDOT priority species for this Study utilize talus natural communities; therefore, this community type was not included in the Study.

Caves and Karst

Karst topography is characterized by porous limestone and dolomite, which erodes easily and leads to the formation of caves, sinkholes, and other landforms developed by erosion. Missouri contains over 8,000 caves (Missouri Speleological Survey (MSS) 2025), primarily in the Ozark Highlands ecoregion (MDC 2024b). Cave land cover data was obtained from the MDC Natural Heritage occurrence record dataset.

Caves make up 1,043 acres in Missouri (less than 0.1 percent of the state's total land area) and primarily occur in the southern half of the state. Most caves are found in the Ozark Highlands ecoregion, with a few occurring in the Central Irregular Plains, Interior River Valleys and Hills, and Western Corn Belt Plains.

Wetlands

Wetlands are unique habitats that can support a variety of both terrestrial and aquatic communities. Typically considered to be transition zones between land and aquatic areas, wetlands are defined by the presence of aquatic vegetation, hydric soils, and hydrologic indicators. Wetlands can occur in many of the other habitat types in Missouri, including forests, woodlands, prairies, and savannas, or adjacent to rivers and streams, and play an essential role in water filtration and flood control, as well as providing habitat for many wildlife species (MDC 2024n).

Wetland data used in this Study was obtained from both the USGS LULC dataset and the National Wetland Inventory (NWI), a database of wetlands maintained by the USFWS (2024b). According to the NWI, Missouri contains approximately 2,284,871 acres of wetlands, or about 5.1 percent of the state's total land area. Wetlands are distributed throughout the state, with significant concentrations along the Missouri and Mississippi River floodplains as well as in other low-lying areas. Missouri wetlands can be categorized by their location in the landscape, vegetative communities, and hydrology:

Freshwater Forested/Shrub Wetlands: This wetland type includes both Palustrine Forested (PFO) and Palustrine Shrub (PSS) wetlands and are typically classified as forested swamps or shrub bogs. PFO and PSS wetlands are found in areas with persistent flooding or saturation and make up approximately 33.5 percent of Missouri's total wetland area.

Riverine Wetlands: Riverine wetlands are found along rivers, streams, and floodplains, and are influenced by the movement of water. These wetlands make up approximately 28.1 percent of Missouri's total wetland area.



Lake Wetlands: Lakeside wetlands are found along the shores of lakes and reservoirs and support both aquatic vegetation and wildlife. Lake wetlands make up approximately 14.0 percent of Missouri's total wetland area.

Freshwater Emergent Wetlands: Freshwater emergent wetlands are classified as Palustrine Emergent Wetlands (PEM). PEM wetlands are dominated by herbaceous plants such as marshes, fens, swales, and wet meadows. They are typically saturated but not permanently flooded. PEM wetlands make up approximately 12.4 percent of Missouri's total wetland area.

Freshwater Ponds: Freshwater ponds consist of ponds and small bodies of standing water, often surrounded by aquatic vegetation. Freshwater ponds are classified as Palustrine Unconsolidated Bottom (PUB) or Palustrine Aquatic Bed (PAB) wetlands and make up approximately 11.9 percent of Missouri's total wetland area.

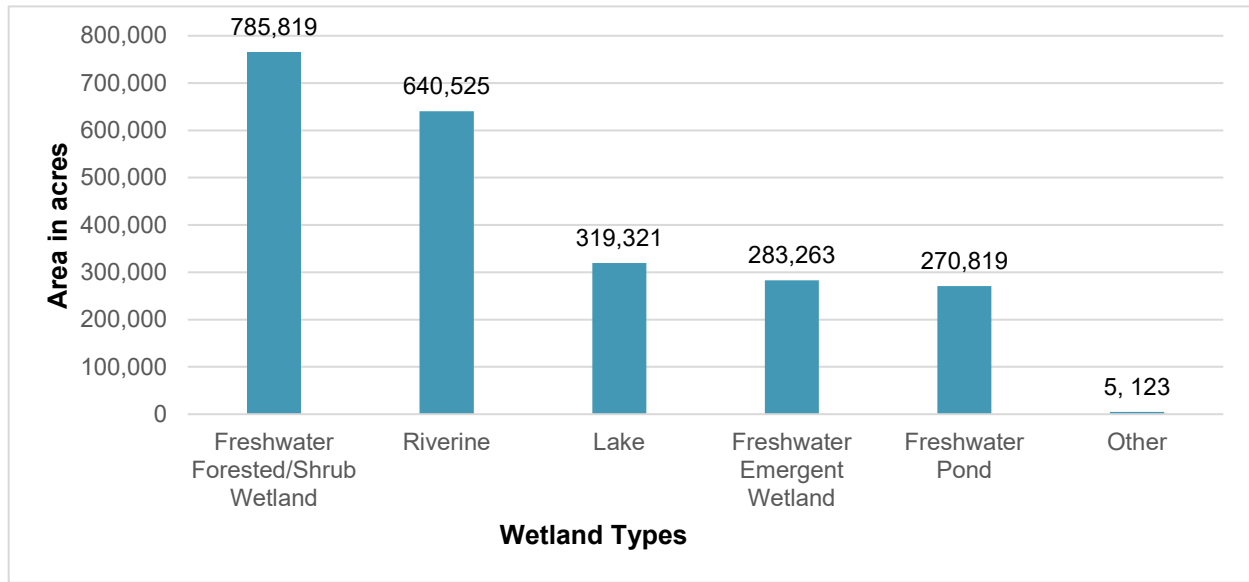
Other Wetlands: This category includes miscellaneous freshwater wetland types such as farmed wetlands, saline seeps, or other unique wetland formations not captured by the previous classifications. These wetlands make up approximately 0.2 percent of Missouri's total wetland area.

Lakes, Ponds, and Reservoirs

Lakes, ponds, and reservoirs are non-flowing bodies of water, either naturally occurring or manmade. Ponds are shallower than lakes and can typically support rooted aquatic plants throughout. Lakes are typically larger, deeper, and often have stratified temperatures. Reservoirs are impoundments created by the damming of a river or stream. Due to the lack of current, lakes, ponds, and reservoirs support unique aquatic communities when compared to the flowing waters of rivers and streams (MDC 2024g). Lake, pond, and reservoir data used in this Study were obtained from the USGS LULC dataset, oxbow records from the MDC Natural Heritage occurrence records, and the USFWS NWI.

The figure below shows the distribution and acreages of NWI wetlands, lakes, ponds, and reservoirs in Missouri.

Figure 2-8: Wetland Types in Missouri



Source: USFWS 2024b.

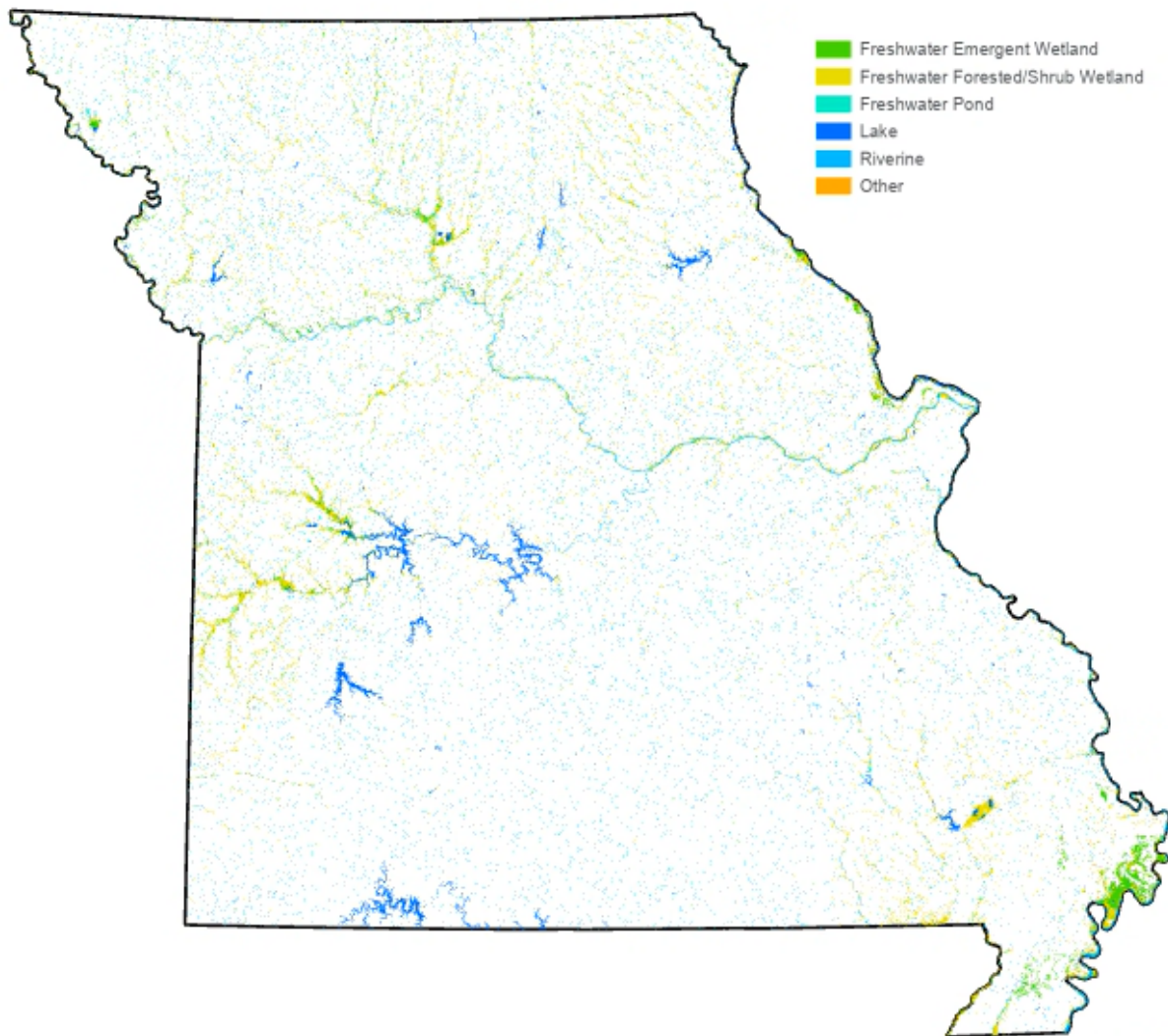
Table 2-14 shows NWI wetland and non-flowing waterbody percentages within each Missouri ecoregion.

Table 2-14: Percentage of Wetland Types within Missouri Ecoregions

Wetland Type	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
Freshwater Emergent	0.6%	0.7%	4.2%	<0.1%	0.1%	1.4%
Freshwater Forested/Shrub	2.4%	2.5%	5.0%	1.7%	0.6%	2.1%
Freshwater Pond	0.9%	0.7%	0.2%	0.7%	0.4%	0.8%
Lake	0.3%	1.1%	0.3%	<0.1%	1.0%	0.3%
Riverine	1.1%	2.4%	2.6%	1.1%	1.2%	1.8%
Other	-	<0.1%	0.2%	-	<0.1%	-

Source: USFWS 2024b.

Figure 2-9: Wetlands and Waterbodies in Missouri



Roadsides and Highly Disturbed Areas

Roadsides and other disturbed areas (such as railroads, golf courses, agricultural lands, and residential lawns) are habitats in which the native plant community is regularly and severely disrupted. This can often lead to the establishment of weedy and/or invasive species; however, certain native plant and animal species have adapted to highly disturbed habitats (MDC 2024j). USGS LULC data was used to represent land cover from this group of natural communities and included developed open space, low intensity development, and cultivated crops.

2.4.2.1 PROTECTED AREAS

Protected areas play a vital role in conserving Missouri's natural resources and biodiversity by providing designated habitat blocks for wildlife, as well as improving habitat connectivity (USGS Gap Analysis Project [GAP] 2024). The USGS maintains a geospatial database of marine and terrestrial protected areas in the United States, known as the Protected Areas Database of the United States (PAD-US). Version 4.0 of PAD-US was used to obtain protected area information for this Study.

Protected areas within the PAD-US database are classified into four categories (referred to as GAP Status Codes) based on the degree of intended management for each site (USGS GAP 2021):

Status 1: Areas that are permanently protected from land cover conversions and have a mandated management plan. Natural disturbance events are allowed to occur without interference and/or are mimicked by management activities. Status 1 sites in Missouri are managed by the U.S. Forest Service, non-governmental organizations, USFWS, and managers of state and private conservation areas.

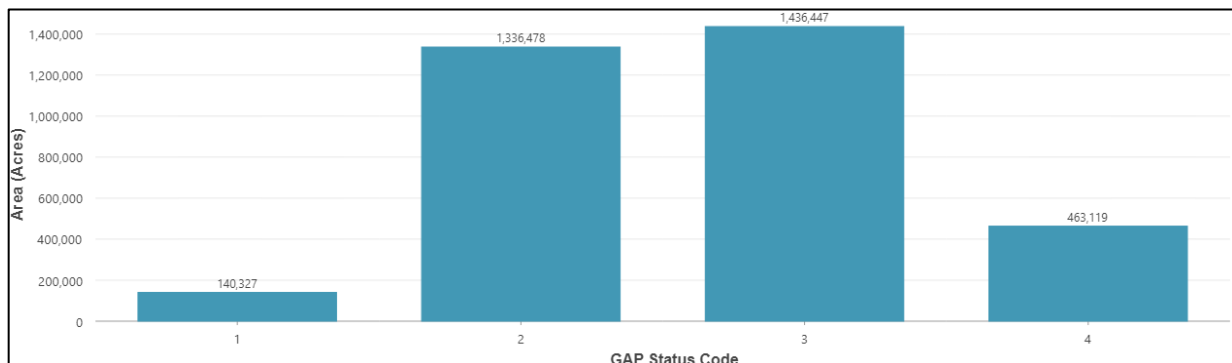
Status 2: Areas that are permanently protected from land cover conversions, but the mandated management plan only seeks to maintain a primarily natural state. These areas may be used or managed in ways that degrade natural systems, including the suppression of natural disturbance events. Status 2 sites in Missouri are managed by the U.S. Army Corps of Engineers (USACE), the U.S. Forest Service, USFWS, National Resources Conservation Service (NRCS), NPS, MDC, the Missouri Department of Natural Resources (MoDNR), non-governmental organizations, and city, county, and regional managers.

Status 3: Areas in which the majority is permanently protected from land cover conversions, but extractive disturbances (either broad, low-intensity disturbance or localized high-intensity disturbance) are allowed. Status 3 sites in Missouri are managed by USACE, Bureau of Land Management (BLM), U.S. Forest Service, and local government managers.

Status 4: Areas that do not have any known public or private mandates and/or do not have legal easements or deed restrictions to prevent land cover conversions. Conversions to unnatural land cover types are allowed and management intent is unknown (USGS GAP 2021). Status 4 sites in Missouri are managed by American Indian Lands, USACE, the Department of Defense (DoD), U.S. Forest Service, NPS, USFWS, MDC, MoDNR, and city, county, and regional managers.

Based on PAD-US data, protected areas in Missouri cover approximately 3,376,371 acres, which represent about 7.6 percent of the state's total land area. The figure below shows the distribution of protected areas in Missouri, based on the GAP Status Codes.

Figure 2-10: Protected Area Acreages within Missouri



Source: USGS GAP 2024



Table 2-15 shows the percentage of each GAP Status Code within protected areas in each Missouri ecoregion.

Table 2-15: Percentage of Land Designated as Protected Areas in Missouri Ecoregions

Status Code	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
1	0.1%	0.2%	0.5%	<0.1%	4.1%	<0.1%
2	2.1%	3.2%	3.7%	1.8%	27.4%	2.9%
3	<0.1%	0.3%	<0.1%	<0.1%	56.3%	0.1%
4	0.6%	1.0%	0.1%	-	12.2%	0.4%

Source: USGS GAP 2024.

Figure 2-11: Protected Areas in Missouri

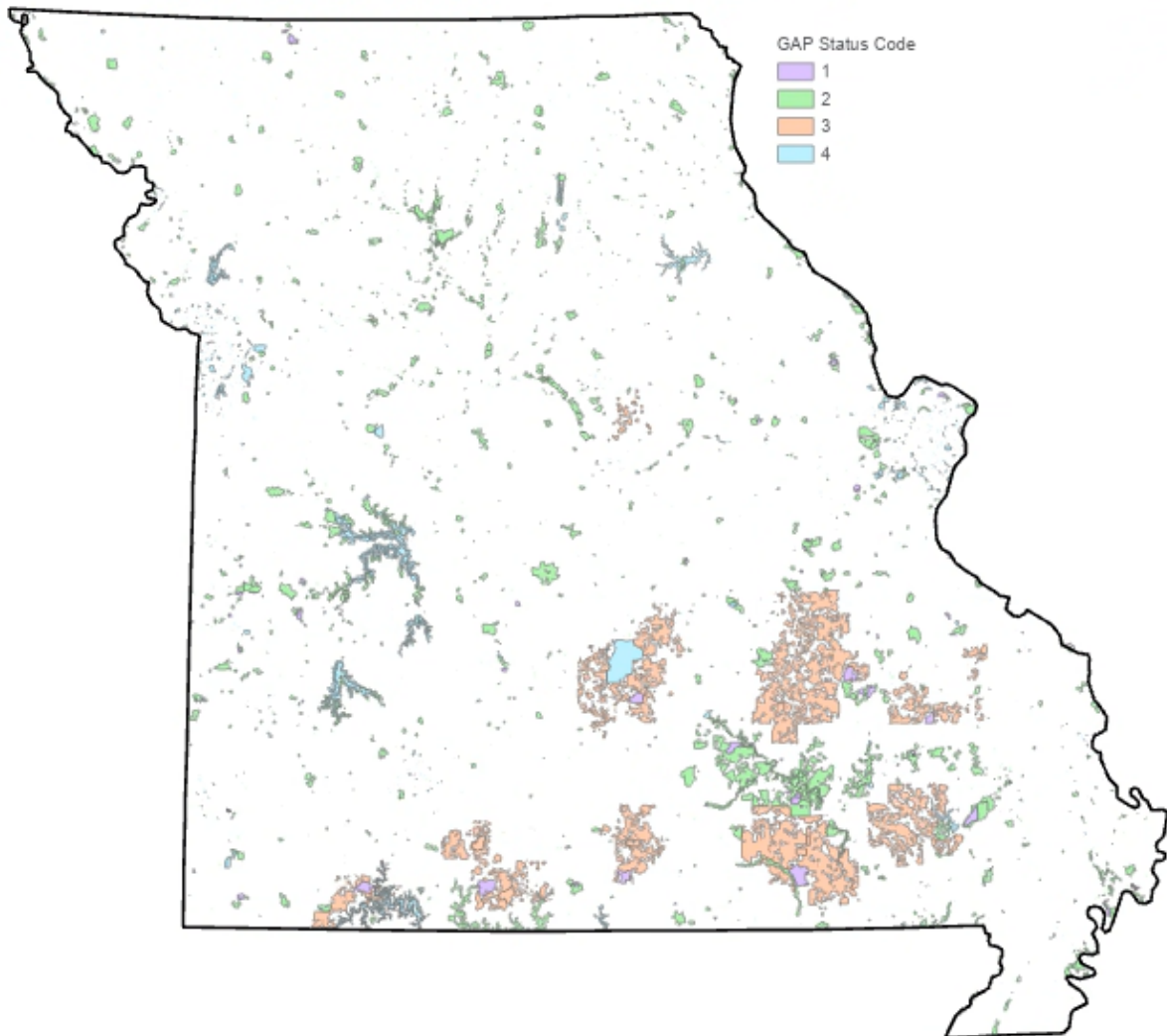




Table 2-16: Acreage of Protected Areas in Missouri by Management Name/Type

Management Name	Status Code 1 Acres	Status Code 2 Acres	Status Code 3 Acres	Status Code 4 Acres
American Indian Lands	-	-	-	1
BLM	-	-	54	-
City Land	-	2,025	-	41,344
County Land	-	2,523	-	16,892
DoD	-	-	-	80,250
Joint	-	-	-	1,882
Local	2,786	1,985	-	70
MDC	-	209	-	1,648
MoDNR	-	0.2	-	2
Non-Governmental Organization	14,502	16,914	-	13,320
NPS	-	-	-	282
NRCS	-	164,818	-	358
Other or Unknown Federal Land	-	2	220	359
Other or Unknown Local Government	-	-	0.1	25
Other or Unknown State Land	-	140	-	2,830
Private	2,638	117,925	-	2,318
Regional Agency Land	-	17	-	694
Research/Education	-	-	702	168
State	48,610	856,939	-	7,284
USACE	-	35,748	90	292,481
USFWS	9,917	58,558	-	299
U.S Forest Service	64,511	15,400	1,435,380	68
Unknown	-	180	-	543

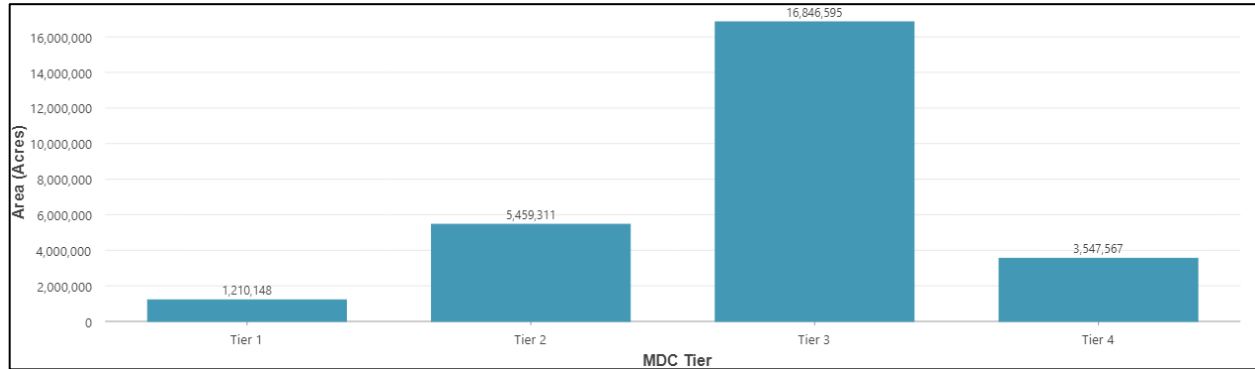
Source: USGS GAP 2024.

Missouri maintains an additional habitat designation database, known as the MDC Tiered Approach to Natural Community and Habitat Management, which is outlined in the MDC Comprehensive Conservation Strategy (CCS) plan. The approach does not restrict usage or management activities on a site, instead dividing natural areas within the state into four tiers based



on an area's potential for sustainable and/or regenerative conservation and ranging from outstanding (Tier 1) to extremely poor (Tier 4) (MDC 2020c). Based on the MDC data, areas included in the tiered approach cover approximately 27,063,621 acres, which represent about 60.7 percent of Missouri total land area. The figure below shows the distribution of MDC Tiers within Missouri.

Figure 2-12: MDC Tiers within Missouri



Source: MDC 2020c.

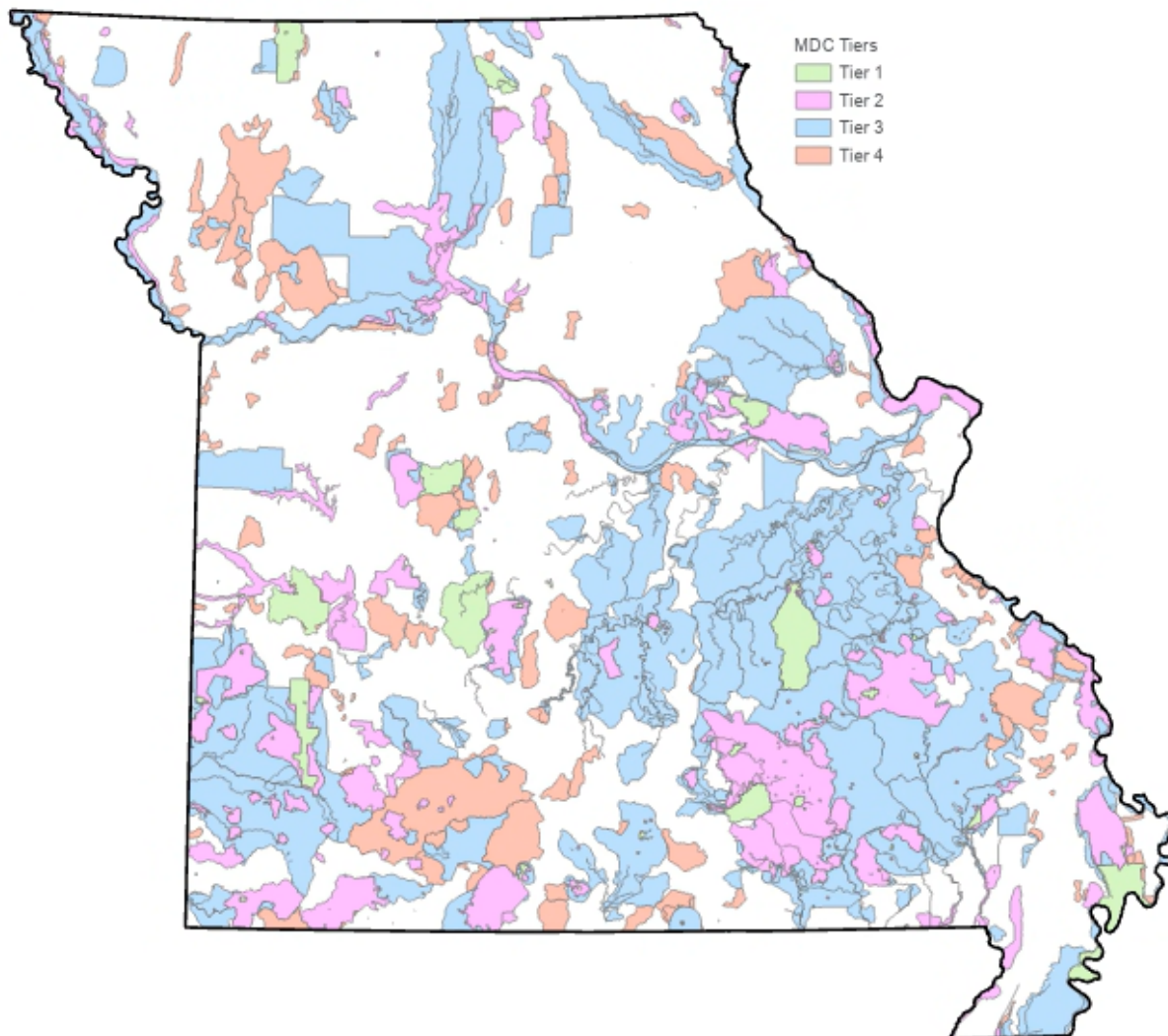
Table 2-17 shows the percentage of each MDC Tier within each Missouri ecoregion.

Table 2-17: Percentage of MDC Tiers in each Missouri Ecoregion

Tier	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
1	3.6%	1.1%	7.2%	0.1%	3.2%	0.1%
2	9.8%	14.9%	19.1%	1.7%	17.2%	8.2%
3	42.9%	27.8%	56.6%	29.6%	55.7%	22.1%
4	10.3%	6.4%	3.1%	3.3%	9.4%	4.0%

Source: MDC 2020c.

Figure 2-13: MDC Tiers



2.4.3 Missouri Linkage Zones

Linkage zones, sometimes referred to as wildlife corridors, are natural areas that provide connectivity between habitat blocks (Gregory et al 2021). Linkage zones facilitate wildlife movement for seasonal migrations, foraging, and breeding (Morse 2024). Preserving linkage zones between habitat blocks improves overall habitat connectivity, which by extension improves gene flow, as well as adaptability and resiliency to population pressures (Rudnick et al. 2012). For this Study, predominant types of linkage zones within Missouri were defined using the MDC natural community groupings, as well as a dataset of continuous American black bear landscape suitability obtained from a study conducted by Gantchoff et al. (2022), which was extrapolated to represent general linkage zones throughout the state.

Rivers and Streams

Rivers and streams in Missouri are defined as running water in ephemeral, intermittent, or perennial channels. Rivers and streams connect many other habitats, support aquatic



communities throughout the state (MDC 2024i), and provide linkage zones between habitat blocks.

River and stream data for the Study was obtained through the USGS National Hydrography Dataset (NHD). The dataset shows streams, rivers, and artificial flow paths (USGS 2023a). Rivers and streams can be differentiated from each other based on average flow and are classified as ephemeral (streams that are rain-dependent and only flow following precipitation), intermittent (streams that have seasonal flow), and perennial (streams that flow year-round and are fed from upstream waters and/or groundwater) (US Environmental Protection Agency [USEPA] 2024). Based on NHD data, rivers and streams in Missouri cover approximately 187,123 miles.

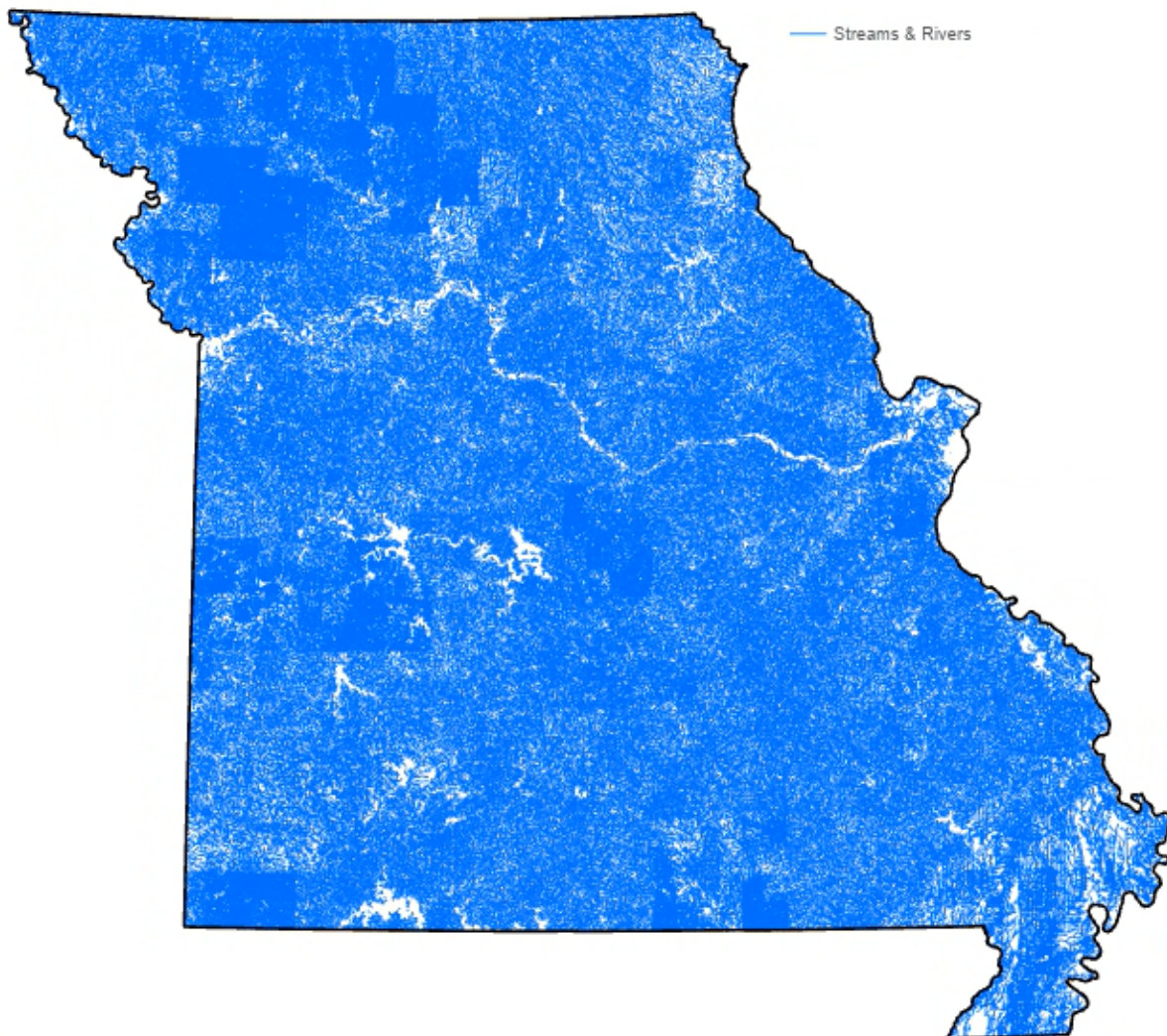
Table 2-18 shows the mileage of rivers and streams within each Missouri ecoregion.

Table 2-18: Length of NHD Waterbodies in each Missouri Ecoregion

Missouri Ecoregions	Length of NHD Waterbodies (miles)
Central Irregular Plains	62,731
Interior Valleys and Hills	20,671
Mississippi Alluvial Plain	8,478
Mississippi Valley Loess Plains	1,057
Ozark Highlands	80,467
Western Corn Belt Plains	13,719

Source: USGS 2023a.

Figure 2-14: Streams and Rivers in Missouri



Stream Edges and Riparian Zones

Stream edges (areas directly adjacent to rivers and streams) support distinct natural communities that are adapted to frequent flooding. Stream edges include sandbars, gravel washes, and stream/riverbanks. Habitats and characteristics of stream edge communities vary depending on soil type, adjacent plant and animal communities, velocity of the water, and stream gradients, among other factors (MDC 2024I).

Riparian zones are broad groups of streamside habitats that include stream edges, floodplains, and bottomlands. Riparian zones typically have moist soils and experience frequent flooding events (MDC 2024I). Riparian corridor data for this Study was obtained through the NWI database. According to the NWI, there are 3,606 acres of mapped riparian zones in Missouri, less than 0.1 percent of the state's total land area. **Table 2-19** shows the percentage of mapped riparian zones in each of Missouri's ecoregions.

Table 2-19: Percentage of NWI Riparian Zones in each Missouri Ecoregion

Missouri Ecoregions	NWI Riparian Zones
Central Irregular Plains	<0.1%
Interior Valleys and Hills	-
Mississippi Alluvial Plain	-
Mississippi Valley Loess Plains	-
Ozark Highlands	0.02%
Western Corn Belt Plains	-

Source: USFWS 2024b.

The NWI riparian data was supplemented with a floodplain dataset maintained by the Federal Emergency Management Agency (FEMA). FEMA categorizes floodplains into the following groupings, based on their flood hazard risk (Federal Emergency Management Agency [FEMA] 2023).

Table 2-20: FEMA Floodplain Categories

Flood Zone	Description
A	Areas with a 1% annual chance of flooding (also known as 100-year floodplain).
D	Areas with possible but undetermined flood hazards (no flood hazard analysis has been conducted).
X – Shaded	Areas of moderate flood hazard, between the limits of the 100-year and 500-year floods.
X – Unshaded	Areas of minimal flood hazard determined to be outside the 500-year flood and protected by levee from 100-year flood.

Source: FEMA 2023.

According to FEMA, there are 5,382,459 acres of floodplains (excluding Flood Zone X - Unshaded) within Missouri, or approximately 12.1 percent of the state's total land area (FEMA 2024). Percentages of floodplains and areas of minimal flood hazard (Zone X - Unshaded) in Missouri are outlined in **Table 2-21** below.

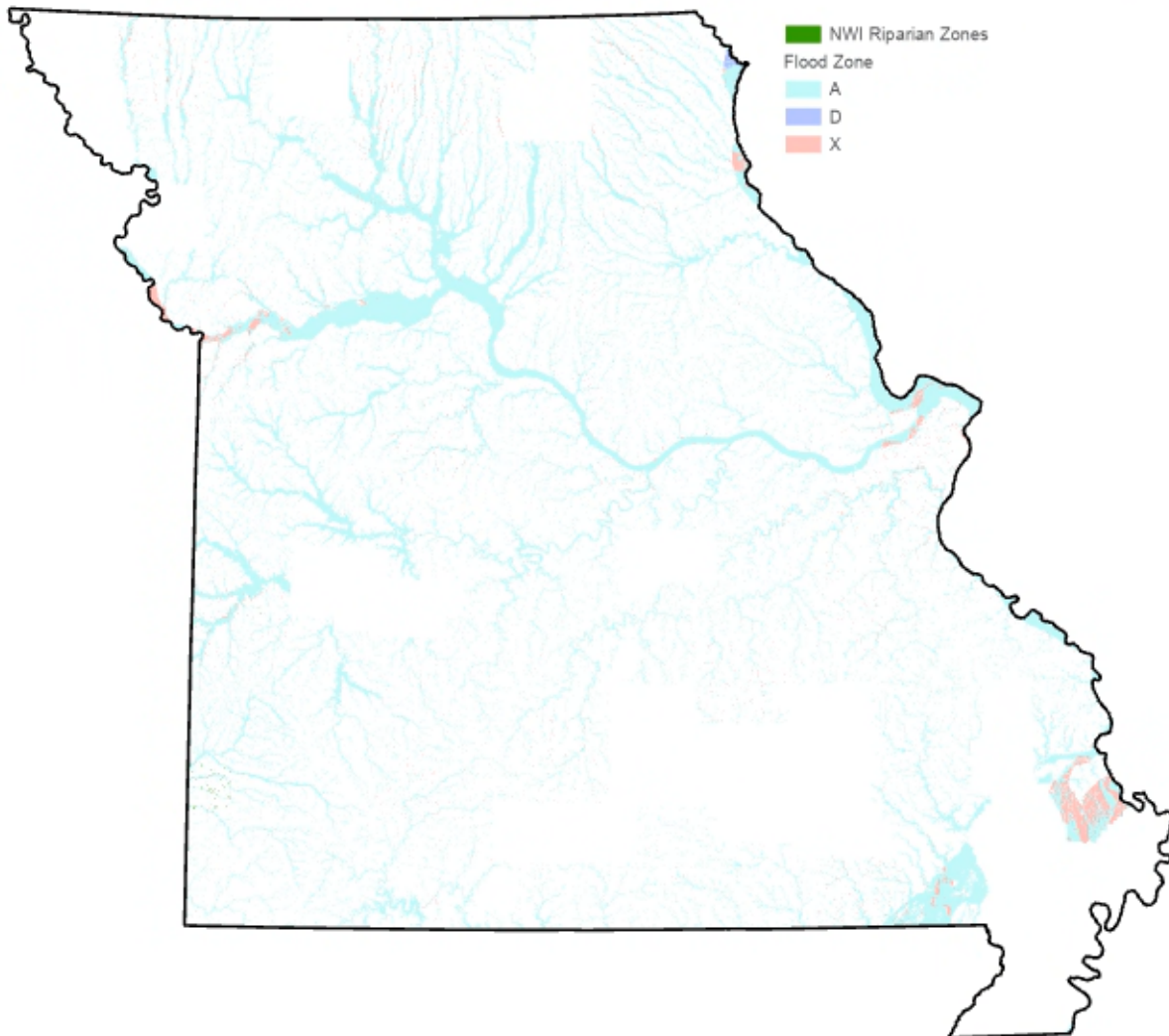
Table 2-21: Percentage of Floodplain Areas in each Missouri Ecoregion

Flood Zone	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
A	14.8%	25.3%	17.5%	<0.1%	8.4%	22.4%
D	-	0.2%	-	-	-	-

Flood Zone	Central Irregular Plains	Interior River Valleys and Hills	Mississippi Alluvial Plain	Mississippi Valley Loess Plains	Ozark Highlands	Western Corn Belt Plains
X – Shaded	<0.1	0.6%	0.5%	-	0.2%	0.6%
X – Unshaded	0.4%	1.3%	4.9%	-	<0.1%	0.9%

Source: FEMA 2024.

Figure 2-15: Missouri Floodplains and Riparian Zones



American Black Bear Continuous Landscape Suitability

The Gantchoff (2022) study used telemetry data collected over a 9-year period to model continuous landscape suitability for American black bear populations in Missouri. The modeled continuous habitat suitability data shows overall landscape connectivity, ranging from low to high, between Missouri habitat blocks.

2.5 Missouri Wildlife and MoDOT Priority Species

Each habitat block in Missouri supports unique natural communities consisting of both plants and animals (hereafter referred to as “wildlife”). The presence of wildlife species within these habitat blocks allows for continued ecosystem functioning by influencing nutrient cycling, populating food webs, and contributing to the overall stability of the ecosystem (Cleland 2011). Missouri is home to hundreds of native wildlife species, each with differing habitat requirements (MDC 2020c; MDC 2024o). For the purposes of this Study, wildlife in Missouri were broadly categorized into groups of similar species. In order to more accurately represent their habitat usage and requirements in Missouri, the mammal grouping was further subdivided into general groups based on size. Mammal size classifications were based on similar groupings utilized by the Tennessee Wildlife Resources Agency (Tennessee Wildlife Resources Agency n.d.) but were revised to better represent Missouri wildlife communities.

The resulting categories of Missouri wildlife include plants; insects and arachnids; birds; small, medium, and large mammals; amphibians; reptiles; and fish and other aquatic species. Small mammals were defined as species such as bats, mice, squirrels, ground squirrels, moles, weasels, and rabbits. The medium mammal grouping includes many mesocarnivores and similar size species such as foxes (*Vulpes spp.*), badgers (*Taxidea taxus*), raccoons (*Procyon lotor*), otters (*Lontra canadensis*), beaver (*Castor canadensis*), opossum (*Didelphis virginiana*), muskrat (*Ondatra zibethicus*), skunks (*Mephitis spp.*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*). Only a few large mammal species remain extant in Missouri and include elk (*Cervus canadensis*), white-tailed deer (*Odocoileus virginianus*), American black bear, and mountain lion (*Puma concolor*).

Table 2-22 details the general habitat preferences of each wildlife group in Missouri.

Table 2-22: Wildlife Habitat Preferences in Missouri

Habitat Type	Plants	Insects and Arachnids	Birds	Small Mammals	Medium Mammals	Large Mammals	Amphibians	Reptiles	Fish and Aquatic Species
Prairies ¹	P	P	P	P	P	P	P	P	U
Savannas ²	P	P	P	P	P	P	P	P	U
Altered Grasslands ³	P	P	P	P	P	P	P	P	U
Forests ⁴	P	P	P	P	P	P	P	P	U
Woodlands ⁴	P	P	P	P	P	P	P	P	U
Glades ⁵	P	P	P	P	U	U	P	P	U
Cliffs ⁶	P	P	P	P	U	U	P	P	U
Talus ⁷	P	P	P	P	U	U	P	P	U
Caves and Karst ⁸	P	P	U	P	U	U	P	P	P
Wetlands ⁹	P	P	P	P	P	U	P	P	P
Lakes, Ponds, and Reservoirs ¹⁰	P	P	P	U	P	U	P	P	P
Roadsides and Highly	P	P	P	P	P	P	P	P	U



Missouri Statewide Wildlife Vehicle Collision Study Current Conditions

Habitat Type	Plants	Insects and Arachnids	Birds	Small Mammals	Medium Mammals	Large Mammals	Amphibians	Reptiles	Fish and Aquatic Species
Disturbed Areas ¹¹									
Rivers and Streams ¹²	P	P	P	U	P	U	P	P	P
Stream Edges and Riparian Zones ¹³	P	P	P	P	P	P	P	P	U

Source: ¹MDC, 2024h; ²MDC, 2024k; ³MDC, 2024f; ⁴MDC, 2024d; ⁵MDC, 2024e; ⁶MDC, 2024c; ⁷MDC, 2024m; ⁸MDC, 2024b; ⁹MDC, 2024n; ¹⁰MDC, 2024g; ¹¹MDC, 2024j; ¹²MDC, 2024i; ¹³MDC, 2024l.

P = Preferred habitat. U = Unsuitable habitat.

Habitat block use and movement patterns through linkage zones within each wildlife grouping influence species-specific WVC risks. **Table 2-23** details the list of MoDOT priority species for the Study, their status and presence within carcass databases, and their preferred habitat type and general range throughout Missouri.

Table 2-23: WVC Study Priority Species Habitat and Range

Species Group	Common Name	Scientific Name	Status ¹	Habitat Type ²	General Range in Missouri ³
Plants	Pondberry	<i>Lindera melissifolia</i>	SE, FE, SOCC	Forests; Woodlands; Wetlands; Stream Edges and Riparian Zones	Ripley County
Birds	Bald Eagle	<i>Haliaeetus leucocephalus</i>	MDC Carcass Data, SOCC	Forests; Woodlands; Cliffs; Wetlands; Stream Edges and Riparian Zones; Lakes, Ponds, and Reservoirs; Rivers and Streams	Statewide
Small Mammals	Indiana Bat	<i>Myotis sodalis</i>	SE, FE, MDC Carcass Data, SOCC	Forests; Woodlands; Caves/Karst; Stream Edges and Riparian Zones; Lakes, Ponds, and Reservoirs; Rivers and Streams	Forested Areas Statewide
	Black-Tailed Jackrabbit	<i>Lepus californicus</i>	SE, MDC Carcass Data, SOCC	Altered Grasslands; Roadsides and Highly Disturbed Areas; Prairies; Savannas	Historic: Southwestern portion. Possibly extirpated.
	Franklin's Ground Squirrel	<i>Poliocitellus franklinii</i>	MDC Carcass Data, SOCC	Prairies; Savannas; Woodlands; Roadsides and Highly Disturbed Areas	Northern quarter
	Thirteen-Lined Ground Squirrel	<i>Ictidomys tridecemlineatus</i>	SOCC	Prairies; Savannas; Altered Grasslands; Roadsides and Highly Disturbed Areas	Northwest portion



Missouri Statewide Wildlife Vehicle Collision Study Current Conditions

Species Group	Common Name	Scientific Name	Status ¹	Habitat Type ²	General Range in Missouri ³
	Least Weasel	<i>Mustela nivalis</i>	MDC Carcass Data, SOCC	Prairies; Savannas; Altered Grasslands; Wetlands	Northern portion
	Long-Tailed Weasel	<i>Neogale frenata</i>	MDC Carcass Data, SOCC	Prairies; Savannas; Woodlands; Stream Edges and Riparian Zones	Statewide
Medium Mammals	American Badger	<i>Taxidea taxus</i>	MDC Carcass Data, SOCC	Prairies; Altered Grasslands; Roadsides and Highly Disturbed Areas	Sparse statewide. More common in northern and western portions
	Plains Spotted Skunk	<i>Spilogale putorius interrupta</i>	SE, MDC Carcass Data, SOCC	Prairies; Savannas; Forests; Woodlands; Altered Grasslands; Roadsides and Highly Disturbed Areas	Statewide but scarce in the bootheel
Large Mammals	White-Tailed Deer	<i>Odocoileus virginianus</i>	MDC Focal Species	Prairies; Savannas; Altered Grasslands; Forests; Woodlands; Glades; Wetlands; Roadsides and Highly Disturbed Areas; Stream Edges and Riparian Zones	Statewide
	American Black Bear	<i>Ursus americanus</i>	MDC Focal Species; SOCC	Forests; Woodlands	Primarily south of Interstate 44
	Elk	<i>Cervus canadensis</i>	MDC Focal Species	Altered Grasslands; Forests; Woodlands; Glades	Carter, Reynolds, and Shannon Counties
Amphibians	Great Plains Toad	<i>Anaxyrus cognatus</i>	MDC Carcass Data, SOCC	Wetlands; Roadsides and Highly Disturbed Areas; Stream Edges and Riparian Zones	Missouri River floodplain, from northwestern corner to the central portion
	Northern Leopard Frog	<i>Lithobates pipiens</i>	SOCC	Prairies; Savannas; Wetlands; Lakes, Ponds, and Reservoirs; Roadsides and Highly Disturbed Areas; Stream Edges and Riparian Zones	Northwestern counties along the Iowa border
	Eastern Tiger Salamander	<i>Ambystoma tigrinum</i>	SOCC	Prairies; Savannas; Wetlands; Lakes, Ponds, and Reservoirs	Statewide but most common in northern half
Reptiles	Alligator Snapping Turtle	<i>Macrochelys temminckii</i>	Proposed FT, SOCC	Wetlands; Lakes, Ponds, and	Southern, southeastern, and eastern portions



Species Group	Common Name	Scientific Name	Status ¹	Habitat Type ²	General Range in Missouri ³
				Reservoirs; Rivers and Streams	
	Blanding's Turtle	<i>Emydoidea blandingii</i>	SE, SOCC	Prairies; Savannas; Wetlands; Lakes, Ponds, and Reservoirs; Roadsides and Highly Disturbed Areas	Extreme northeastern and northwestern corners
	Western Chicken Turtle	<i>Deirochelys reticularia</i>	SE, SOCC	Forests; Wetlands; Lakes, Ponds, and Reservoirs; Stream Edges and Riparian Zones	Extreme southeastern portion
	Western Foxsnake	<i>Pantherophis vulpinus</i>	MDC Carcass Data, SOCC	Prairies; Savannas; Wetlands; Stream Edges and Riparian Zones	Northwestern corner
	Western Mudsake	<i>Farancia abacura</i>	MDC Carcass Data, SOCC	Forests; Woodlands; Wetlands; Lakes, Ponds, and Reservoirs; Roadsides and Highly Disturbed Areas; Stream Edges and Riparian Zones;	Extreme southeastern portion
	Eastern Massasauga Rattlesnake	<i>Sistrurus catenatus</i>	SE, FT, SOCC	Prairies; Savannas; Forests; Woodlands; Wetlands	Historic: Mississippi River floodplain north of St. Louis. Extirpated.
	Kirtland's Snake	<i>Clonophis kirtlandii</i>	SOCC	Prairies; Savannas; Roadsides and Highly Disturbed Areas	Northeast corner along the Mississippi River
Fish	Niangua Darter	<i>Etheostoma nianguae</i>	SE, FT, SOCC	Rivers and Streams	Tributaries of the Osage River
	Topeka Shiner	<i>Notropis topeka</i>	SE, FE, SOCC	Rivers and Streams	Small streams in Central Missouri

¹SE=state endangered; FT=federally threatened; FE=federally endangered

Source: ²MDC, 2020c; ³MDC, 2024a

2.5.1 Priority Species Ecology and Road Interactions

As discussed in **Section 1.2**, a primary goal for the Study is to identify road segments where wildlife crossings could have the highest probability for positively impacting priority species. In order to identify these road segments, an understanding of how specific habitat requirements and life histories of each priority species contributes to their road use and susceptibility to WVCs is essential.

Available research was reviewed for the MoDOT priority species' ecology and usage of wildlife crossing structures. Research on usage of wildlife crossing structures often includes types of

suitable crossing structures for the target species, parameters of crossing structure characteristics (such as width, height, lighting, and moisture levels), and recommendations for material types and maintenance frequency. Wildlife crossing structure research was not available for all the priority species, however, and in such cases a thorough consideration of species life history traits can provide insight into appropriate wildlife crossing structure selection.

2.5.1.1 PLANTS

Roads have been shown to act as a barrier or deterrent to animal movement (Shepard et al. 2008a), which in turn can reduce dispersal distances for plants, particularly those that rely on animals for seed dispersal. One plant species was identified as a priority species for this Study.

Pondberry

Pondberry (*Lindera melissifolia*) is state and federally endangered, and a Missouri SOCC. A shrub with pale, yellow flowers and small, red fruits, pondberry spreads through runners to form colonies. Suitable habitat types include bottomlands and forested wetlands. Pondberry seeds are dispersed by birds and mammals (MDC 2024a), including white-tailed deer, northern cardinal (*Cardinalis cardinalis*), brown thrasher (*Toxostoma nifum*), swamp rabbit (*Sylvilagus* sp.), nine-banded armadillo (*Dasypus novemcinctus*), and gray squirrels (*Sciurus carolinensis*) (Abilio et al. 2008; Martins et al. 2015). Because pondberry dispersal and successful propagation is dependent on the movements of birds and mammals, roads that transect suitable pondberry habitat can have a negative impact on successful seed dispersal due to road avoidance or mortality of dispersal species (Shepard et al. 2008a). A reduction in WVCs for pondberry seed dispersers would likely improve pondberry dispersal. Wildlife crossing structures targeting any of the species known to eat pondberry will likely, by extension, also benefit pondberry dispersal success and population densities.

2.5.1.2 BIRDS

Roads can negatively or positively impact birds in a variety of ways, depending on the life history of each species. Scavengers and predators can be attracted to roadways and road ROWs by the presence of carcasses and/or smaller animals. Various raptor species often hunt in ROWs (Jacobson 2005; USFWS 2024d), and certain bird species may be attracted to roads by the use of salt (Jacobson 2005). Roadways can also impact breeding success and migration patterns, particularly of smaller species, due to noise and light pollution (Cooke et al. 2020; Jacobson 2005). Vegetative communities along roadway ROWs can provide foraging and nesting opportunities (Jacobson 2005; USFWS 2024d). Edge habitat provided by ROWs can positively impact certain generalist species, but the resulting habitat fragmentation can have a detrimental effect on rare or specialist species (Cooke et al. 2020). The attractive properties of roads can increase the proximity of many species to roadways and vehicles, which can in turn increase the likelihood of WVCs (USFWS 2024d).

A variety of wildlife crossing structures have the potential to benefit birds. Low fences can prevent ground-dwelling birds from accessing roadways (USFWS 2024d). Overpasses can provide birds with a safer route for crossing roadways, while underpasses provide terrestrial pathways for ground-dwelling birds to cross roadways (Holmes 2023; USFWS 2024d). Reduction of overall WVCs can reduce the frequency and amount of carcasses, the presence of which often attracts

scavengers such as bald eagles (*Haliaeetus leucocephalus*) and turkey vultures (*Cathartes aura*) (Goldfarb 2023; Holmes 2023; USFWS, 2024d).

One bird species was identified as a priority species for this Study.

Bald Eagle

The bald eagle is an SOCC in Missouri and is protected federally by the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (MDC 2024a). Formerly a federally endangered species, the bald eagle is considered a success story of the Endangered Species Act (ESA) (USFWS 2021). Bald eagles primarily eat fish and carrion, and are frequently found near lakes, rivers, and marshes adjacent to forested areas. Bald eagles nest in tall trees or sometimes cliffs within approximately 2 miles from a large water source (USFWS 2020). As populations continue to increase, bald eagle ranges are also increasing and often now include urban areas (USFWS 2021). Like other scavengers, bald eagles are susceptible to WVCs while feeding on carcasses (Slater et al. 2022; USFWS 2024d). Bald eagle carcasses have been noted in the MDC carcass database.

Bald eagle mortalities due to WVCs are closely related to the presence of carcasses along roadways. Carcasses pose an ecological trap for bald eagles and other scavenging birds and mammals (Singh et al. 2024). The installation of wildlife crossing structures targeted at reducing WVCs involving terrestrial wildlife have been shown to also decrease bald eagle mortalities (Goldfarb 2023; Slater et al. 2022). In areas where permanent wildlife crossing structures are not feasible, studies have found that moving carcasses at least 40 feet away or removing them from roadways entirely may effectively reduce bald eagle WVCs (Goldfarb 2023; Slater et al. 2022).

2.5.1.3 SMALL MAMMALS

Small mammals have been shown to avoid roads (Brehme et al. 2013; Shepard et al. 2008a), particularly paved roads (Brehme et al. 2013), which can lead to habitat fragmentation and reduced ranges (Myczko et al. 2017). The vegetative composition of roadway ROWs often provide attractive habitat for many small mammal species; however, the resulting close proximity with roadways can increase WVCs and mortality of those species (Adams and Geis 1983).

Species in this group generally prefer crossing structures containing protective features for cover (such as rocks, logs and stumps, vegetation, or smaller pipes), as many of these animals are prey species (Kintsch and Cramer 2011). Numerous small mammal species have been shown to benefit from overpasses, viaducts/flyovers, underpasses, and modified culvert designs (Clevenger and Huijser 2011; Kintsch and Cramer 2011). Canopy crossings and amphibian/reptile tunnels can also be suitable if modified to meet local species requirements (Clevenger and Huijser 2011), as some species in this group require specific substrate, moisture, or other features for a crossing structure to be suitable (Kintsch and Cramer 2011).

Six small mammal species were identified as priority species for this Study.

Indiana Bat

The Indiana bat (*Myotis sodalis*) is a federally and state endangered species. Federal critical habitat for the species has been established in southeastern Missouri, partially overlapping with Mark Twain National Forest. Populations throughout the United States have sharply declined in

recent years, largely due to the spread of White Nose Syndrome, a fungal disease that impacts bats during hibernation (USFWS 2024c). Indiana bats hibernate in caves or mines during the winter, and roost under loose tree bark in tree crevices or cavities during the summer (MDC 2024a). Potentially suitable roost trees include live and dead hardwood trees that have shingle-like or loose bark, or trees with cavities, splits, crevices, hollow sections, and other damage. Individual trees which exhibit these qualities are only considered suitable habitat if located within 1,000 feet of forested habitat. Indiana bats may also utilize human-made structures such as buildings, barns, and bridges for roosting (USFWS 2024c). Suitable Indiana bat foraging habitat includes forested/wooded habitats of varying density and canopy closure, forest edges of larger forest openings, riparian corridors through forests, and open water (USFWS 2024c).

Roadways bisecting areas of suitable foraging and roosting habitat can pose both a mortality risk and act as a habitat barrier for Indiana bats. Bats fly closer to the ground in areas with little or no canopy cover, putting them at higher risk for vehicle collisions when crossing roads (Russell et al. 2009). The habitat surrounding roads has also been shown to influence mortality risk: roads which cross flyways (forest and stream corridors or forest edges) often have higher bat mortality rates than roads that do not bisect flyways (Lesinski 2007). Roads can also lead to fragmentation of suitable habitat. When commuting between areas of suitable habitat, Indiana bats have been shown to avoid roads, particularly when vehicles are present. Traffic volume appears to be the most limiting factor for road avoidance (Zurcher et al. 2010). Indiana bats carcasses have previously been noted in the MDC carcass database.

Insectivorous bats, such as the Indiana bat, have been shown to use wildlife underpasses to cross roadways (Bhardwaj et al. 2017). When presented with road crossings options including culverts, underpasses, or no wildlife crossings, insectivorous bats preferred utilizing the underpasses (Bhardwaj et al., 2017). *Myotis* species (including the Indiana bat) in particular have been shown to prefer underpasses to overpasses or other types of wildlife crossing structures (Martinez-Medina et al. 2021). However, studies have also shown that artificially lit underpasses are unattractive to insectivorous bat species, as the light may increase their risk of predation by other species (Bhardwaj et al. 2019).

When considering the installation of potential wildlife crossing structures to benefit bats, the level of clutter-adaptation for a particular species has been shown to be a determining factor in preference between underpasses and overpasses (Martinez-Medina et al. 2021). Likewise, above-road wildlife crossing structures should be continuous across the road at canopy-level in order to route the animals out of the path of traffic (Kintsch and Cramer 2011). Other life history traits may also influence wildlife crossing structure usage by specific bat species, and priority bat species should be identified prior to wildlife crossing structure selection.

Black-Tailed Jackrabbit

The black-tailed jackrabbit (*Lepus californicus*) is state endangered and an SOCC in Missouri. The large rabbits prefer habitats consisting of open plains, grasslands, pastures, cultivated crops, and hay fields with good visibility (MDC 2022a). They prefer to forage in areas near protective cover, typically shrubby areas (Ferguson et al. 2012). Although uncommon and possibly extirpated in Missouri, black-tailed jackrabbits are widespread throughout the western United States. In areas with high population density, black-tailed jackrabbits are susceptible to WVCs

and increased risks of predation due to lack of cover near roadways (Ferguson et al. 2012). Black-tailed jackrabbit carcasses have previously been noted in the MDC carcass database.

Black-tailed jackrabbits usage of and preferences for wildlife crossing structures are poorly studied, but the species has been observed using underpasses in several western states (Cramer et al. 2022a; Cramer and Hamlin 2019). A study conducted for the Washington State DOT showed that black-tailed jackrabbits will use underpasses of varying sizes (both culverts and bridge underpasses), in addition to wildlife overpasses (Kintsch and Cramer 2011). Underpasses should be relatively dry (not submerged) and larger crossing structures should contain moderately-sized rock and/or vegetation to provide areas of cover (Kintsch and Cramer 2011). Substrate composition (natural or artificial) does not appear to be a limiting factor for black-tailed jackrabbit use of wildlife crossing structures (Kintsch and Cramer 2011).

Figure 2-16: Black-tailed jackrabbit using a wildlife underpass along U.S. 89 in Utah.



Source: Cramer and Hamlin 2019.

Franklin's Ground Squirrel

Franklin's ground squirrel (*Poliocitellus franklinii*) is an SOCC in Missouri. The ground squirrels prefer edge habitats along the transition from forest to grassland (woodlands) and populations have been declining throughout their range due to habitat fragmentation (MDC 2024a). Roadway and railroad ROWs often provide attractive habitat for Franklin's ground squirrels, and the ground squirrels are often seen crossing or adjacent to roads (MDC 2024a). This close proximity to roadways increases their risk of mortality from WVCs. Franklin's ground squirrel carcasses have previously been noted in the MDC carcass database.

Minimal research exists on Franklin's ground squirrel use of wildlife crossing structures. However, Kintsch and Cramer (2011) found that mammals exhibiting moderate mobility (including rabbits, ground squirrels, weasels, and other small mammals) generally have similar preferences and requirements for wildlife crossing structures. Therefore, the same crossing structures discussed for black-tailed jackrabbits are likely a suitable starting point for projects targeting Franklin's ground squirrels. However, the frequent use of roadway ROWs as suitable habitat by Franklin's

ground squirrels (Illinois Department of Natural Resources [DNR] 2024; MDC 2024a) may pose a unique set of challenges when attempting encourage the use of wildlife crossing structures and reduce the number of WVCs.

Thirteen-Lined Ground Squirrel

The thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*) is an SOCC in Missouri. Smaller than the Franklin's ground squirrel, the thirteen-lined ground squirrel has thirteen distinctive stripes along its back (MDC 2024a). Their preferred habitat includes grasslands dominated by short grasses, including developed landscapes such as golf courses (MDC 2024a). Mowed and maintained roadway ROWs may also provide attractive habitat for thirteen-lined ground squirrels (Illinois DNR 2024). Similar to the Franklin's ground squirrel, living in close proximity to roads may increase their mortality risk from WVCs.

Thirteen-lined ground squirrel use of wildlife crossing structures has also been poorly studied. However, the suitability and challenge assumptions outlined above for Franklin's ground squirrels can likely be applied as a starting point for thirteen-lined ground squirrels as well.

Least Weasel

The least weasel (*Mustela nivalis*) is an SOCC in Missouri. These small, brown and white carnivores prefer habitats with short, sparse ground cover, such as pastures, harvested fields, and marshes. Least weasels typically have large litters that disperse after approximately three months. The weasels are highly territorial, with home ranges of up to 60 acres per mating pair (Minnesota DNR 2024). Habitat fragmentation from roads coupled with the territorial nature of the least weasel may cause them to be at high risk for WVCs during dispersal and foraging activities. Additionally, highly fragmented habitats due to roads transecting their habitat has the potential to reduce rodent populations, which are the primary food source for the least weasel (Minnesota DNR 2024), as well as reducing foraging ranges. Least weasel carcasses have previously been noted in MDC's carcass database.

Minimal research exists for least weasel usage of wildlife crossing structures. Least weasels are included in the moderate mobility mammal group established by Kintsch and Cramer (2011); therefore, similar suitable structures to those discussed for the black-tailed jackrabbit, Franklin's ground squirrel, and thirteen-lined ground squirrel are likely a reasonable starting point for the design of wildlife crossing structures targeting least weasels.

Long-Tailed Weasel

Larger than the least weasel, the long-tailed weasel (*Neogale frenata*) is also an SOCC in Missouri. Their preferred habitat includes woodlands, brushy riparian corridors, and fencerows (MDC 2024a). Long-tailed weasel have been shown to rely on habitat connectivity and have exhibited sensitivity to habitat fragmentation within their home ranges (Gehring and Swihart 2004). They primarily feed on small mammals, including mice, voles, and chipmunks (MDC 2024a). Long-tailed weasels may be negatively impacted by habitat fragmentation due to roads and may be attracted to roadway ROWs by the presence of their preferred prey. Long-tailed weasel carcasses have previously been noted in the MDC carcass database.

Long-tailed weasels have been observed using both small and large culverts to cross under roadways (Bellis 2008; City of Wilsonville 2024; Hillard 2023). Similar to the least weasel, other wildlife crossing structures targeting moderately mobile mammals (Kintsch and Cramer 2011) will likely benefit long-tailed weasels as well.

2.5.1.4 MEDIUM-SIZED MAMMALS

Medium-sized mammals have been shown to have some of the highest rates of WVCs among North American mammals (Barthelmess and Brooks 2010; Cook and Blumstein 2013; Ford and Fahrig 2007; Hill et al. 2020). Many medium-sized mammals are omnivores and scavengers, both of which typically have larger foraging ranges than herbivores (Cook and Blumstein 2013; Ford and Fahrig 2007; Hill et al. 2020). The larger the foraging range, the higher the likelihood of animals coming in contact with roads (Ford and Fahrig 2007; Hill et al. 2020). Additionally, scavenging behaviors can make roads an attractive source of food in areas where carcasses are present (Hill et al. 2020). Although large mammals (and especially carnivores) also tend to have large foraging ranges, their larger body sizes make them easier for motorists to see and avoid than medium sized mammals (Barthelmess and Brooks 2010; Ford and Fahrig 2007; Hill et al. 2020). Many medium-size mammals are nocturnal, which also increases their vulnerability to WVCs due to limited motorist visibility in the dark (Cook and Blumstein 2007; Sullivan 2011).

Similar to small mammals, medium-sized mammals prefer crossing structures containing protective features for cover (Kintsch and Cramer 2011) and have been shown to use medium and large underpasses, viaducts, modified culverts, and wildlife overpasses (Ament et al. 2021; Clevenger and Huijser 2011; Kintsch and Cramer 2011).

Two medium-sized mammals were identified as priority species for this Study.

American Badger

The American badger (*Taxidea taxus*) is an SOCC in Missouri due to habitat fragmentation. American badgers are heavy-bodied, with white and black markings on the face. Their preferred habitat includes prairies, grasslands, agricultural lands, pastures, and open, grassy developed areas such as parks (MDC 2024a). A nocturnal species, American badgers typically have ranges of up to 2.5 square miles (MDC 2024a). Roads can fragment their habitat and increase the likelihood of road crossings if their home range is transected by roadways. American badgers are also at increased risk of WVCs due to their nocturnal behavior and ability to utilize grassy disturbed habitats, such as roadway ROWs. American badger carcasses have previously been noted in the MDC carcass database.

American badgers have been photographed using medium and large-sized culverts (Cramer 2012; Saunders 2020). Viaducts and wildlife overpasses are also suitable crossing methods for American badgers (Kintsch and Cramer 2011), although their preferred crossing methods and conditions have been poorly studied.

Figure 2-17: An American badger used a wildlife underpass under U.S. 97, south of Bend, Oregon.



Source: C. Oedekirk, Oregon State University, and Oregon Dept. Of Transportation.

Plains Spotted Skunk

The plains spotted skunk (*Spilogale putorius interrupta*) is state endangered and an SOCC in Missouri. Preferred habitat for the plains spotted skunk includes open areas such as prairies, grasslands, agricultural lands, and shrubland that contain areas of adequate brushy cover (MDC 2024a). The skunks are nocturnal and primarily feed on insects, small live mammals, and carrion of larger mammals (MDC 2024a). Their nocturnal nature may cause the skunks to be more susceptible to WVCs during dispersal or while foraging for food due to lower-visibility conditions for motorists. Additionally, the presence of carcasses may attract the skunks to roadways. Plains spotted skunk carcasses have previously been noted in the MDC carcass database.

Plains spotted skunk use of and preferences for specific wildlife crossing structures has been poorly studied. The skunks are classified as moderately mobile by Kintsch and Cramer (2011), however, therefore wildlife crossing structures targeting medium mammal movements will likely be suitable for plains spotted skunks as well.

2.5.1.5 LARGE MAMMALS

In general, large mammals are less likely to be involved in WVCs than medium mammals (Barthelmess and Brooks 2010; Cook and Blumstein 2013; Ford and Fahrig 2007; Hill et al. 2020), primarily because of faster movement across roads and higher visibility due to their larger body mass (Cook and Blumstein 2013). However, large mammals are negatively impacted by roads in many of the same ways as smaller mammalian species and pose a unique threat to motorists. Large mammal populations can be negatively impacted by fragmented habitat as well as physical and genetic isolation between populations (Zeller et al. 2020). Large mammals also typically have broader ranges and travel farther to forage and hunt when compared to mammals with smaller body masses (Cook and Blumstein 2013; Zeller et al. 2020), which increases the likelihood they will interact with roadways. Likewise, the majority of the large mammals in Missouri are omnivores or herbivores. Animals with these diets typically have higher population densities when compared

to carnivores (Cook and Blumstein 2013; Ford and Fahrig 2007), which can also increase the risk of WVCs.

In addition to concerns regarding population impacts, WVCs involving large mammals often result in more severe collisions, which also increases the mortality risk to both the animal and the motorist (Zeller et al. 2020). Because of the unique challenges posed by large mammal road crossings, three of the four large mammal species in Missouri were identified as priority species for this Study.

White-Tailed Deer

White-tailed deer (*Odocoileus virginianus*) are common throughout Missouri and are an MDC focal species. The deer will utilize a variety of habitats, including forested areas, prairies, old fields, agricultural lands, transitional areas between woodlands and agriculture, riparian corridors, and urban areas (Acharya et al. 2023; MDC 2024a; Mori et al. 2024; Pierce et al. 2022). White-tailed deer are herbivores and have been known to destroy crops (MDC 2024a; Mori et al. 2024; Pierce et al. 2022) and are often attracted to roadway ROWs by the presence of suitable foraging opportunities (Donaldson et al. 2016; Fairbank 2013; Waring et al. 1991). The deer are crepuscular, and therefore most active around dawn and dusk. Crepuscular activity patterns can increase risk of WVCs due to limited motorist visibility and coincidence with heavier traffic volumes (Acharya et al. 2023; Finder et al. 1999). Other life history traits that make white-tailed deer particularly susceptible to WVCs include increased deer activity due to rutting behaviors during the breeding season (Acharya et al. 2023; Finder et al. 1999), dispersal of young in the spring (Finder et al. 1999), the presence of suitable foraging habitat adjacent to roadways, and roadways bisecting movement corridors, especially riparian corridors (Acharya et al. 2023).

As of 2025, 1.7 million white-tailed deer were estimated to be present in Missouri (MDC 2025b). A white-tailed deer management plan was developed by MDC in 2014, which includes hunting guidance to help control population levels (Acharya et al. 2023; MDC 2014; MDC 2024a). Despite ongoing management, white-tailed deer WVC risks exist for motorists in both urban and rural areas in Missouri (Acharya et al. 2023). In 2022, MoDOT estimated that motorists in Missouri have a 1 in 74 chance of being involved in a deer-related WVC (Acharya et al. 2023; MoDOT 2022b). In 2023, almost 3,600 WVCs involving deer were reported on Missouri roads, four of which resulted in human fatalities (MoDOT 2024).

White-tailed deer have been known to use large underpasses, culverts, viaducts, and overpasses (Ament et al. 2021; Kintsch and Cramer 2011), although bridge underpasses appear to be preferred over culverts (Andis et al. 2017; Cramer and Hamlin 2017). Crossing structure width and height, level of openness, and presence of cover are important factors in usage of crossing structures (Cramer and Hamlin 2017; Donaldson 2005). Crossing structures should be wide and relatively short (<100 feet) (Kintsch and Cramer 2011). Good visibility and moderate cover both within and adjacent to the structure has also been shown to help improve habitat connectivity and attract deer to the structure (Andis et al. 2017; Donaldson 2005; Kintsch and Cramer 2011).

Figure 2-18: White-tailed deer regularly use wildlife crossing structures and other existing infrastructure that facilitate streams and rivers across the U.S.



Source: Montana Department of Transportation and P. Cramer.

Fencing has been shown to increase usage of crossing structures by white-tailed deer, as well as reducing deer-related WVCs, by excluding deer from roadways and directing them to appropriate crossing locations (Donaldson and Elliott 2020; Donaldson et al. 2016; Fairbank 2013). Fencing should be at least 8 feet tall with no top-mounted outrigger (Osborn et al. 2010). Associated jump-outs and escape ramps should be less than 5 feet tall, as white-tailed deer have exhibited hesitancy of using jump-outs and escape ramps 5 or more feet tall (Huijser and Getty 2023).

American Black Bear

The American black bear (*Ursus americanus*) is an MDC focal species. The large, black bears are predominantly found in the southern portion of Missouri, but individual bears are sporadically observed throughout the rest of the state (MDC 2024a). American black bears were once thought to be extirpated from Missouri, but in recent years populations and ranges throughout the state have grown (Gantchoff et al. 2022; MDC 2020a; MDC 2024a). In 2020, MDC released a management plan for the bears, which includes population management goals (including a highly regulated hunting season), and human/bear conflict reduction goals (MDC 2020a). Black bears prefer forested habitat and are omnivorous, eating grasses, fruits, insects, fish, small mammals, bird eggs, and carrion (MDC 2024a).

American black bear foraging and dispersal strategies, as well as their increasing range and populations, heightens their risk of roadway interactions and susceptibility to WVCs. In the 2023 Missouri Black Bear Program Annual Report, MDC listed nine bear fatalities caused by WVCs (MDC 2023). Black bear WVCs bring the same risks to humans as white-tailed deer WVCs. American black bears are large animals, weighing anywhere between 86-900 pounds (MDC 2024a), and can pose a significant risk to human safety when involved in WVCs.

Black bears have been shown to utilize a variety of wildlife crossing structures including overpasses, dry bridges, and culverts (Clevenger and Waltho 2005; Jones et al. 2008; Kintsch

and Cramer 2011). Black bears have been observed using culverts as small as 6.56 x 5.91 feet; however, little is known about their preferred structure size and/or characteristics (Clevenger and Waltho 2005; Jones et al. 2008; Sawaya et al. 2013). Structures linking areas of suitable habitat on each side of the road are preferred (Jones et al. 2008), and close proximity of human structures or residences can act as a deterrent to wildlife crossing structure usage (Clevenger and Waltho 2005; Jones et al. 2008). Fencing used in combination with wildlife crossing structures for American black bears should be at least 10 feet tall and be partially buried, with metal posts to discourage the bears from climbing up the fence posts (Jones et al. 2008).

Figure 2-19: American black bear regularly used wide open underpasses in Colorado under State Highway 9 (Kintsch et al. 2021).



Source: Colorado Dept. Of Transportation, Colorado Parks and Wildlife, ECO-resolutions, and P. Cramer.

Elk

Elk (*Cervus canadensis*) are an MDC focal species. Previously found statewide, elk were extirpated from Missouri by the 1880s (MDC 2024a). From 2011 to 2013, a reintroduction effort was conducted to begin establishing and increasing elk populations (MDC 2024a). Historically, elk were typically found in woodlands, open forests, and pastures where they graze on both herbaceous and woody vegetation (MDC 2024a). Reintroduced elk are currently found in Carter, Shannon, and Reynolds counties (MDC 2018) and primarily feed in cultivated food plots until their populations are better established (MDC 2024a). MDC released an elk management plan in 2020, outlining population management and public engagement goals, as well as hunting guidelines (MDC 2020b).

Similar to American black bears, elk are large animals that can weigh 500-830 pounds (MDC 2018; MDC 2024a). As elk populations and ranges continue to expand, so too does the risk of interactions with roadways and the potential for WVCs. As with white-tailed deer and American black bears, the elk's large size can pose a health risk to humans who are involved in WVCs.

Studies have shown that elk prefer overpasses to underpasses (Kintsch et al. 2021; Cramer and Hamlin 2025; Simpson et al. 2016). If underpass structures are the only option, elk are known to

use short, wide (less than 100 feet long and at least 15 feet wide) culverts and arched culverts; however, these structures are not known to facilitate functional connectivity for all members of a herd (Kintsch and Cramer 2011, Kintsch et al. 2021; Cramer and Hamlin 2025). The preferences for providing connectivity for elk should be large bridge underpasses and wildlife overpasses, rather than culverts, (Cramer 2012; Dodd et al. 2007; Kintsch et al. 2015). Eight feet high fencing should be used in combination with crossing structures to direct elk to the crossing locations (Cramer 2012; Gagnon et al. 2015). Additionally, a high degree of visibility should be maintained in spaces both within and adjacent to the crossing structures (Dodd et al. 2007; Kintsch and Cramer 2011; Kintsch et al. 2015). Elk have also been shown to prefer natural substrates and side slopes, with noise and light contrast moderation (Kintsch and Cramer 2011).

Figure 2-20: A herd of elk using the US 160 overpass at Chimney Rock, Colorado.



Source: Colorado Dept. Of Transportation, Southern Ute Indian Tribe, and Wildlife Connectivity Institute.

2.5.1.6 REPTILES AND AMPHIBIANS

Due to herpetofauna life history strategies, overland dispersal patterns, migration, and slow movement, reptiles and amphibians are particularly susceptible to WVCs (Gunson et al. 2016; Western Ecological Research Center 2018; Woltz et al. 2008). Amphibian breeding sites, as well as dispersal and migration corridors are often transected by roads, which increases the risk of WVCs and species mortality (Briggler 2024; Ochs et al. 2024; Cayuela et al. 2019). Reptiles, including both turtles and snake species, are equally susceptible to WVCs. Female turtles can travel up to 0.2 miles to lay eggs, increasing their likelihood of crossing a road (Briggler 2024). Habitat fragmentation can also increase the risk of WVCs for many turtle species (Briggler 2024; Paterson et al. 2021). Snakes commonly migrate from summer habitat in floodplains to upland overwintering habitat and are especially susceptible to WVCs in areas where migration corridors are transected by roads (Briggler 2024). Additionally, roads may present an attractive warm surface for snakes to absorb heat, further increasing mortality risks (Briggler 2024). A study conducted in Illinois found that roads intersecting high quality reptile habitats had higher mortality rates than did roads through low quality habitats, regardless of traffic volume (Shepard et al. 2008b).

Herpetofauna will utilize many types of wildlife crossing structures, including underpasses, overpasses, viaducts, and specialized culverts (Kintsch and Cramer 2011); however, many of these species are small and slow-moving and may have specific habitat condition requirements, such as light or moisture. Crossing structures geared towards these species should consider species-specific habitat requirements, and should ensure that suitable conditions, such as substrate, light, temperature, and moisture, are consistent throughout the entire structure (Jochimsen et al. 2004; Kintsch and Cramer 2011; Woltz et al. 2008). Some species in this group, for example, rely on celestial bodies for navigation and/or require dry pathways to traverse alongside waterways (e.g. flowing water through culverts). In such cases, installing only partially enclosed culverts and/or including dry ledges above the waterline in culvert design can help tailor wildlife crossing structures to low mobility species

Three amphibian and seven reptile species were identified by MoDOT as priority species for this Study.

Great Plains Toad

The great plains toad (*Anaxyrus cognatus*) is a Missouri SOCC. The toad is medium-sized and covered in gray, brown, green, or yellow patches, each encircled with a white border (MDC 2024a). The Great Plains Toad is found exclusively in floodplains along the Missouri River in central and northwestern Missouri (MDC 2024a). Exhibiting explosive breeding after heavy rains, the toads utilize floodplains, flooded fields, and roadside ditches for breeding during the late spring and summer (Briggler 2024). Breeding locations are often transected by roads, which can pose a high mortality risk for the species. Live and dead individuals have been documented on Missouri roads (Briggler 2024) and carcasses have previously been noted in the MDC carcass database.

Because great plains toads frequently utilize flooded roadside ditches for breeding (Briggler 2024), they are particularly susceptible to WVCs during the breeding season. Minimal research has been conducted on great plains toad wildlife crossing structure preferences or requirements; however, Minnesota DNR found that culverts used in combination with fencing may be beneficial for reducing roadway access and subsequent WVCs (LeClere 2018).

Northern Leopard Frog

The northern leopard frog (*Lithobates pipiens*) is a Missouri SOCC. The frog is medium-sized and green or brown with large black or reddish spots on its back (MDC 2024a). The northern leopard frog is found in the far northwestern corner of Missouri along the Iowa border (MDC 2024a). Overwintering and breeding habitat consists of permanent water bodies, including wetlands, floodplains, ponds, lakes, and ditches. During the summer, the frogs migrate to grasslands and prairies (Knutson et al. 2018; MDC 2024a), dispersing potentially up to 1.8 miles (Knutson et al. 2018). Mortality risk due to WVCs is relatively low due to low population densities in Missouri. Known colonies of northern leopard frogs in Missouri are located far from roadway corridors (Briggler 2024).

Northern leopard frogs have been shown to exhibit minimal road avoidance; areas with both high northern leopard frog population densities and high traffic volumes can have detrimental effects on northern leopard frog populations (Bouchard et al. 2009). Locations with known northern

leopard frog populations and/or locations planned for reintroduction should be carefully evaluated for the presence of nearby roads and associated traffic volume (Bouchard et al. 2009).

Because of their lack of road avoidance, prevention of road crossings is the preferred method used to reduce northern leopard frog WVCs through a combination of structures such as drift fencing with modified culverts and/or modified bridges (Bouchard et al. 2009; Woltz et al. 2008). Use of signage for drivers may also benefit the species (Bouchard et al. 2009). Northern leopard frogs have been shown to prefer modified culverts/tunnels with a diameter larger than 1.6 feet wide and a length of less than 30 feet. Associated fencing (to funnel the frogs into the culverts) should be at least 2 feet high (Woltz et al. 2008).

Eastern Tiger Salamander

A medium to large sized salamander, the eastern tiger salamander (*Ambystoma tigrinum*) is typically brown or black in color and is covered with yellow or olive-colored spots (MDC 2024a). The salamanders are found statewide (MDC 2024a) and migrate between ponds and wetlands, where they breed in late winter to early spring, and savannas and prairies where they spend the non-breeding season (Briggler 2024). Roads can pose a high mortality risk for this species if transected by migration routes (Briggler 2024), in addition to causing habitat fragmentation (Ochs et al. 2024). Both live and dead individuals have been documented on roads in Missouri (Briggler 2024).

Like the northern leopard frog, underpasses used in combination with fencing have been shown to reduce eastern tiger salamander mortalities from WVCs (Ochs et al. 2024). Tunnel length, entrance width, and moisture level within the tunnels all contribute to tunnel usage (Ochs et al. 2024). Similar salamander species have exhibited avoidance of traditional culverts; however, eastern tiger salamander-specific research on the usage of and preferences for other wildlife crossing structures, including traditional culverts, has been poorly studied (Ochs et al. 2024).

Alligator Snapping Turtle

Alligator snapping turtles (*Macrochelys temminckii*) are large, fully aquatic turtles with strong, hooked beaks. They are proposed threatened federally and an SOCC in Missouri. The turtles utilize deep sloughs, oxbow lakes, deep pools in large rivers, reservoirs, and streams (MDC 2024a). Dispersal and movement take place in aquatic environments, while reproduction (egg laying) occurs in terrestrial habitats adjacent to permanent bodies of water. Due to their nearly fully aquatic life history, alligator snapping turtles have a relatively low risk of mortality due to WVCs (Briggler 2024) but may be negatively impacted by altered stream flows and habitat fragmentation caused by roadway stream crossing infrastructure such as culverts. Alligator snapping turtle usage of wildlife crossing structures has been understudied. However, studies conducted for similar species (such as the common snapping turtle [*Chelydra serpentina*]) have shown that semi-submerged culverts or underpasses used in combination with barrier walls to restrict access to roadways have been successful in facilitating crossings (Heaven et al. 2019). Common snapping turtles utilized tunnels and culverts with a diameter of greater than 1.6 feet, and fencing/barrier walls at least 2 feet tall were effective in keeping them from roadways (Woltz et al. 2008). Alligator snapping turtles can grow much larger than common snapping turtles (Will County Forest Preserve District 2021); however, and while these parameters may provide a basis for the design of wildlife vehicle crossing structures, culvert/tunnel sizes should be appropriately

scaled to the target species. Additionally, barrier fencing should be carefully chosen and routinely maintained as the presence of gaps and holes can trap turtles on roadways and contribute to increased species mortality from WVCs (Baxter-Gilbert et al. 2015).

Blanding's Turtle

These medium-sized turtles are black or brown with yellow spots or bars on their upper shells. Blanding's turtles (*Emydoidea blandingii*) are state endangered and an SOCC in Missouri. They are semi-aquatic, utilizing terrestrial habitats such as prairies and grasslands, as well as aquatic habitats including wetlands, ponds, and drainage ditches (MDC 2024a). Blanding's turtles can take up to 20 years to reach sexual maturity, and adult females typically lay only one clutch of eggs per year (Compton 2007). Females can travel long distances to lay eggs (Briggler 2024), making them particularly susceptible to WVCs (Department of Defense [DoD] 2022), and both eggs and juveniles often have a low survival rate (DoD 2022; Massachusetts Division of Fisheries and Wildlife 2015). Because of this life history strategy, it is estimated that Blanding's turtle populations require a greater than 95 percent annual adult survival rate to maintain population levels (Compton 2007; Massachusetts Division of Fisheries and Wildlife 2015). In addition to direct mortality from WVCs, Blanding's turtles have demonstrated reluctance to cross roads, which can further exacerbate the effects of habitat fragmentation on populations (Proulx et al. 2014). When roads crossings are attempted, this species has a high risk of mortality from WVCs in areas where roads transect or parallel prairie and wetland mosaic habitats. Both live and dead individuals have been documented on roads in Missouri (Briggler 2024).

Minor modifications to existing roadway infrastructure can help to reduce Blanding's turtle mortality from WVCs. Seasonal vehicle speed reduction methods, such as speed bumps, and turtle crossing signage may help to reduce the risk of breeding season mortalities in areas where more permanent wildlife crossing structures are not feasible (DoD 2022). Curbed roads also pose an extreme hazard to Blanding's turtles, as they have difficulty climbing over curbs and can become trapped on roadways (Ballesterio et al. 2023; Minnesota DNR 2008). Modified curbs (no more than 4 inches high with a 3:1 slope) or the conversion of curbs to ditches can help alleviate this issue (Ballesterio et al. 2023; Minnesota DNR 2008). Low-sloped, vegetated riparian embankments along roadways can make roadway access easier for the turtles; increasing the grade of the slope and adding rip rap can help to block access to roadways (Ballesterio et al. 2023).

Blanding's turtles have also been shown to benefit from wildlife crossing structures. Fencing is an effective way to prevent access to roadways, provided the fencing is opaque with no gaps, is at least 2 feet tall with a 4-inch overhang, is entrenched at least 6 to 8 inches into the ground, and is well-maintained (Ballesterio et al. 2023). Fencing should also stretch 20 feet beyond the terminus of the hot spot (Ballesterio et al. 2023).

Fencing used to funnel the turtles into culverts or underpasses is especially effective at reducing risk of WVCs (Ballesterio et al. 2023; DoD 2022; Massachusetts Wildlife Climate Action Tool 2017). Culverts and underpasses should have natural substrates (Ballesterio et al. 2023) and an opening of at least 36 inches (Minnesota DNR 2008). Light is an important factor in wildlife crossing structure usage by turtles; culverts should have grated ceiling opening to provide light (Ballesterio et al. 2023). Additionally, all culverts should be regularly maintained to prevent

blockages (Ballesterio et al. 2023). Blanding's turtles are semi-aquatic but are not strong swimmers; therefore, culverts and underpasses should not be submerged (Ballesterio et al. 2023) and in-stream crossing locations should be flat-bottomed and twice as wide as the stream (Minnesota DNR 2008).

MoDOT has previously installed wildlife crossing structures specifically targeting Blanding's turtles and the state endangered yellow mud turtle (*Kinosternon flavescens*) along a 1-mile section of MO Route 27. Exclusionary fencing was constructed along the east side of Route 27 in the 1990s, but no monitoring efforts have been conducted since that time (MoDOT 2023).

Western Chicken Turtle

These small, light brown turtles are rare in Missouri, occurring only in the far southeast corner of the state. They are state endangered and an SOCC in Missouri. Western chicken turtles (*Deirochelys reticularia miaria*) are semi-aquatic, often traveling far distances to find suitable aquatic habitats, including slow-moving river oxbows, still lakes, swamps, and ephemeral wetlands (MDC 2024a). The turtle spends most of its time in terrestrial bottomland forested environments close to suitable aquatic habitats (Briggler 2024). This species has a high risk of mortality from WVCs where roads transect or parallel the limited bottomland forest habitats. Live individuals have been documented on roads in Missouri, and mortalities due to WVCs would likely be higher if populations were more abundant (Briggler 2024).

Minimal research exists on the use of and preferences for wildlife crossing structures for the western chicken turtle. Species life history strategies should be considered when designing wildlife crossing structures for poorly studied species.

Western Foxsnake

The western foxsnake (*Pantherophis ramspotti*) is a moderately-sized tan snake with distinctive brown spots along its body. Rare in Missouri, the western foxsnake occurs only in the far northwestern corner of the state and is an SOCC. Preferred habitat includes prairies, grasslands, and forest edges that adjoin wetlands and floodplains (MDC 2024a; Shew et al. 2012). The snake migrates between summer foraging habitat and hibernation areas (Shew et al. 2012). The western foxsnake is easily spotted on roads due to its size; however, they have a moderate risk of mortality due to WVCs when roads transect or parallel their habitat (Briggler 2024). Western foxsnake carcasses have previously been noted in the MDC carcass database.

Minimal research exists on the use of and preferences for wildlife crossing structures for the western foxsnake. Seasonal road closures where possible may benefit western foxsnakes by reducing the risk of WVCs during migration (Shew et al. 2012). Species life history strategies should be considered when designing wildlife crossing structures for poorly studied species.

Western Mudsake

Western mudsnakes (*Farancia abacura reinwardtii*) are an SOCC and are found in naturally-occurring swamps in the bootheel of Missouri. The snakes are typically medium-sized with black bodies and a red checkered belly (MDC 2024a). The species is semi-aquatic, preferring hardwood forest bottomlands, wetlands, swamps, stream edges, lakes, and occasionally drainage ditches (MDC 2024a). Although easily visible on roads due to their size, western mudsnakes have a high

risk of mortality from WVCs where roads transect or parallel their limited preferred habitat. Both live and dead individuals have been found on roads in southeastern Missouri (Briggler 2024). Western mudsnake carcasses have previously been noted in the MDC carcass database.

Minimal research exists on the use of and preferences for wildlife crossing structures for the western mudsnake. Species life history strategies should be considered when designing wildlife crossing structures for poorly studied species.

Eastern Massasauga Rattlesnake

The eastern massasauga rattlesnake (*Sistrurus catenatus*) suffered extreme habitat loss in the 1800s and early 1900s due to human development, agriculture, and changes to natural hydrology (MDC 2015b). Historically found in the Mississippi River floodplains, the eastern massasauga is small, gray to black with large brown or black spots on the back and sides (USFWS 2024a). Today, the snake is federally threatened and state endangered, as well as being an SOCC in Missouri. The eastern massasauga is a semi-aquatic species, moving between wetlands and upland prairies, woodlands, and forests (Indiana DNR 2024). Presumed extirpated from Missouri, the eastern massasauga has a low risk of mortality from WVCs due to little or no extant populations within the state (Briggler 2024; MDC 2024a). However, a study conducted for the Michigan DOT in 2024 showed that eastern massasauga are negatively impacted by habitat fragmentation caused by roads and will utilize roadway ROWs that exhibit suitable habitat characteristics, particularly in fragmented habitats, increasing their risk of mortality from WVCs (Rajewski et al. 2024).

Life history traits for the eastern massasauga rattlesnake are similar to those of the western foxsnake. Seasonal road closures where possible, therefore, may also benefit eastern massasauga rattlesnakes and reduce the risk of WVCs during migration (Shew et al. 2012). Underpasses/culverts in combination with fencing have also shown to be successful in reducing eastern massasauga rattlesnake mortalities due to WVCs in locations where the fencing was regularly maintained (Colley et al. 2017).

Kirtland's Snake

Kirtland's snake (*Clonophis kirtlandii*) is a small to medium reddish-brown snake with many dark spots on its body. Rare in Missouri due to habitat loss, the snake is an SOCC and is found along the Mississippi River in the northeastern corner of the state (MDC 2024a). Preferred habitats include bottomland prairies and grasslands; however, loss of native grasslands has caused Kirtland's snake to utilize roadside ditches and roadway ROWs as their primary habitat (Briggler 2024). This congregation of snakes near roadways results in a high risk of WVCs throughout their remaining range. Both live and dead individuals have been found on roads in Missouri (Briggler 2024).

Minimal research exists on the use of and preferences for wildlife crossing structures for Kirtland's snake. Species life history strategies should be considered when designing wildlife crossing structures for poorly studied species.

2.5.1.7 FISH

Fish and other fully aquatic species can also be negatively impacted by roads. Roadway infrastructure required for crossing over rivers, streams, and other bodies of water include culverts, dams, weirs, and other such structures (Fleming and Neeson 2020; Jager et al. 2001). Despite allowing water to continue flowing, these structures often alter the existing flow and can act as a barrier to aquatic species, effectively changing aquatic community structures and fragmenting the existing habitat (Fleming and Neeson 2020; Jager et al. 2001; Perkin et al. 2015). The resulting impacts of this fragmentation include loss of genetic diversity, isolated populations, and, in extreme cases, extirpation (Fleming and Neeson 2020; Jager et al. 2001).

Wildlife crossing structures for fish species include modified culverts carefully designed to meet both stream characteristic requirements (such as peak flows and channel depths) and the needs of target aquatic species (such as water velocity, bed material, and migration movement) (Jackson 2003; U.S Forest Service Stream-Simulation Working Group 2008; Kilgore et al. 2010).

Two fish species were identified as priority species for this Study.

Niangua Darter

The Niangua darter (*Etheostoma nianguae*) is federally threatened and state endangered in Missouri, as well as being an SOCC. Federal critical habitat has been established for the species along portions of the Niangua, Little Niangua, and Pomme de Terre Rivers, as well as along Tavern Creek and Brush Creek in central and southwestern Missouri. The fish is large and slender, with two black spots on the base of its tail (MDC 2008a; MDC 2024a). The Niangua darter was previously widespread throughout Missouri, but due to habitat loss and fragmentation is now primarily only found in the Niangua and Little Niangua Rivers (MDC 2008a; MDC 2024a). The darter prefers creeks and small streams with moderate currents that contain run/riffle sequences and pools and require swiftly moving water for spawning (MDC 2024a). Reservoir construction, stream channel disruption from road crossings and elevated culverts, and agricultural runoff have contributed to the decline of this species (MDC 2024a). MDC has shown that commonly used low water crossing culverts can act as aquatic barriers for the Niangua darter by altering stream velocities, which can result in unsuitable flow through the culverts and ultimately lead to habitat fragmentation (Dabbs 2015; Graham 2020; MDC 2015a). Culverts can also frequently become clogged with debris, which can block passage for the fish (Dabbs 2016; Graham 2020; MDC 2015a). Wildlife crossing structures recommended to facilitate Niangua darter passage include the replacement of existing culverts and pipes with low water bridges (Dabbs 2016; Graham 2020; Missouri Conservation Heritage Foundation 2025). MoDOT, MDC, and partners have previously replaced several culverts with low water bridges throughout the Little Niangua River watershed, which has helped improve habitat connectivity (Dabbs 2015; Graham 2020; Missouri Conservation Heritage Foundation 2025) and Niangua darter population densities (Graham 2020).

Topeka Shiner

The Topeka shiner (*Notropis topeka*) is a federally and state endangered minnow. It is also an SOCC in Missouri. The shiner forms schools in runs and pools of small upland creeks (MDC 2024). They prefer moderately clear waters and spawn in silt-free gravel substrates (MDC 2024a). Similar to the Niangua darter, Topeka shiner population declines have been linked to loss of

habitat due to habitat fragmentation from roadway culverts, as well as poor water quality (MDC 2022b).

Various potential blockages for the Topeka shiner have been studied in order to determine the types of wildlife crossing structures best suited to the species' needs. Topeka shiners have been shown to make successful passages in a variety of water depths, velocities, culvert drops, and culvert slopes, as well as within a variety of culvert materials (Blank et al. 2011; Bouska and Paukert 2010). However, some combinations of variables allow for higher passage success rates than others (Blank et al. 2011; Bouska and Paukert 2010). Large structures set low enough in the stream bed to maintain a natural substrate (Blank et al. 2011; MDC 2008b) and containing deep waters with low velocities were noted as providing the best passage conditions for the Topeka shiner (Blank et al. 2011). Light level preferences within culverts have also been studied; however, many factors contribute to culvert lighting, and light levels in isolation do not appear to be a limiting factor for Topeka shiner passage through culverts (Kozarek et al. 2017). To bypass some of the factors that contribute to culvert suitability, MDC instead recommends the use of span bridges rather than culverts, to better facilitate species passage and migration (MDC 2015c).

2.5.2 Priority Species Habitat Analysis

Priority species ecology and behavior was used to identify areas of predicted habitat (locations that contain suitable landcover and hydrological characteristics for each of the priority species) and areas of occupied habitat (locations where priority species have been observed). The resulting areas of predicted and occupied habitat for each priority species were then included as variables in the wildlife vehicle collision ranking in order to identify road segments where wildlife crossings could have the highest probability of benefiting MDC priority species. **Appendix D** shows predicted and occupied habitat areas for each priority species.

2.5.2.1 PRIORITY SPECIES PREDICTED HABITAT METHODOLOGY

Predicted suitable habitat layers were developed for each priority species in order to account for potential species' range shifts and/or increases in the future. The layers were developed by cross-referencing preferred habitat blocks for each species as defined by MDC with available ecoregion information and geospatial datasets, including landcover, protected areas, wetlands, rivers and streams, topography, floodplains and riparian corridors, bridges/culverts, and MDC Natural Heritage Data for cliffs, caves/karst, glades, and oxbows.

NHD data used for the predicted habitat layers was limited to only show streams, rivers, canals, and ditches. The resulting data was further filtered to only include relatively permanent aquatic features, including all perennial streams and intermittent streams with a mean annual flow greater than 2.0 cubic feet per second. A 20-foot buffer was added to the linear features to encompass riparian zones not captured by the NWI riparian data. **Appendix D** details the relevant datasets and methodology used to develop each species layer.

2.5.2.2 PRIORITY SPECIES OCCUPIED HABITAT METHODOLOGY

Occupied habitat layers were also developed for each priority species in order to account for known occurrences throughout Missouri. The MDC Natural Heritage Data records include spatial and qualitative information on areas where MDC surveys have observed SOCCs; these records were used as the basis for occupied habitat layer development. Additional data sources used in



the development of occupied habitat layers included MDC data for a Topeka shiner experimental population and MDC telemetry data for elk. American black bear data was obtained from the Gantchoff et al. (2022) study that used a habitat suitability model to analyze American black bear populations in Missouri and identified core, marginal, and highly marginal habitat patches in order to predict American black bear population growth and future expansion.

Following consultation with the TAC, a 5-mile buffer was placed around occurrence records of all but seven of the MoDOT priority species. The previously developed suitable habitat layers were then clipped to the buffer to create the final occupied habitat layers. Occupied habitat layers for the remaining seven species (Indiana bat, elk, American black bear, white-tailed deer, eastern massasauga rattlesnake, Niangua darter, and Topeka shiner) were developed as follows:

Indiana Bat

The suitable habitat layer was clipped to the federally designated critical habitat in southeastern Missouri, and a 5-mile buffer was added to the MDC Natural Heritage Data records.

Elk

Suitable habitat was clipped to a 1-mile buffer around the MDC elk telemetry data due to the telemetry data providing a more accurate representation of their distribution than the MDC Natural Heritage Data.

American Black Bear

Gantchoff et al. (2022) spatial data for core, marginal, and highly marginal habitat was obtained from the author and used to represent occupied American black bear habitat.

White-Tailed Deer

Due to the widespread nature of white-tailed deer populations, their ability to utilize a wide variety of habitats, and representation in the MSHP crash data, no occupied habitat layer was developed.

Eastern Massasauga Rattlesnake

Since the eastern massasauga rattlesnake is considered extirpated from Missouri, no occurrence records were present within the MDC Natural Heritage Data and therefore no occupied habitat layer was developed.

Niangua Darter

The suitable habitat layer was clipped to the federally designated critical habitat in southwestern Missouri, and a 5-mile buffer was added to the MDC Natural Heritage Data records.

Topeka Shiner

MDC occurrence records and spatial data for an experimental population in northern Missouri were used to develop the occupied habitat layer. A 10-mile buffer was placed around MDC Natural Heritage Data records that fell outside the experimental population range. The NHD data was clipped to the buffer for these occurrences, and the resulting layer was merged with the experimental population data.

3 Wildlife Vehicle Conflict Ranking

3.1 Criteria Identification

In order to identify and rank wildlife vehicle conflict hot spots at a statewide scale, the Project team, in cooperation with the TAC, identified a suite of criteria representing transportation safety, wildlife ecology, and feasibility that could quantitatively rank the 68,912, 0.5-mile segments. Each of the segments was scored for the transportation, ecological, and feasibility criteria, resulting in a final quantitative score. The score for each segment was then fed into the OHSA for a final hot spot map of prioritized wildlife-vehicle conflict areas based on final segment scores. This approach considers areas where wildlife populations are encountering roads and 1) are not successfully crossing (reflected by WVC hot spots), 2) are not attempting to cross roadways due to barriers or traffic volume and connectivity is interrupted, or 3) are successfully crossing roads but may not do so successfully in the future due to increases in traffic volume or changes to roadway design. The prioritization methodology is intended to locate areas with both highway human safety concerns and ecological value to Missouri's wildlife and identify locations with the greatest likelihood for implementation of mitigation. These criteria were heavily influenced by the current conditions assessment.

Table 3-1: Prioritization Criteria, Scores, Importance, and Scoring Method on how Each Road Segment Was Evaluated for Each Criteria.

Criteria	Max Score	Importance of these Data	Formula for Scoring
Transportation Criteria			
Wildlife-Vehicle Crash Hot Spots	20	The crash hot spots are an important part of these analyses and including them at this level helps to maintain the MoDOT mission of making roads safer for motorists.	99% Confidence Interval = 20 points 95% Confidence Interval = 10 points 90% Confidence Interval = 5 points
Wildlife crashes per 0.5-mile segment per year	10	Provides more value to 0.5-mile segments with crashes that were not in hot spots.	WVC Count / 5 years * 4.17 (multiplied by 4.17 to standardize values within score range)
Crashes with Fatality and/or Serious Injuries	10	This scoring is to help elevate potential road segments that could be candidates for Highway Safety Improvement Program funding for traffic safety. This was approved by MoDOT traffic safety.	If the road segment contains either type of crash = 10 points
Percentage of All Crashes that are WVC	10	This helps elevate rural area hot spots that might not have as many crashes/mile as urban areas, but where WVC are of greater concern and safety issue for residents of those rural areas.	WVC / all crashes * 10 (multiplied by 10 to standardize values within score range)
Ecological Criteria			
Traffic Volume = AADT	10	Is a surrogate for areas where wildlife may not even attempt to cross the road due to the fence-like effect of high traffic volumes.	AADT $\geq$ 10,000 = 10 points AADT is $\geq$ 2,000 and < 10,000 = 7 points AADT < 2,000 AADT = 0 points
Occupied Habitat	10	Occupied habitat of priority species is an important indicator of the presence of these species, their vulnerability to the effects of roads, and the biodiversity richness of an area that any wildlife	Within a mile of occupied habitat (not deer), 1 point per species up to 10 points



Criteria	Max Score	Importance of these Data	Formula for Scoring
		mitigation could help maintain and continue to restore.	
Suitable Habitat	5	Suitable habitat is a measure of how important an area is for priority species but has not been verified to be occupied by that species.	Intersects suitable habitat (not deer), 0.5 point per species / 2 (divided by 2 to standardize values within score range)
MDC CCS Management Tiers	15	Represent areas in the state the Missouri Department of Conservation indicate have high ecological values.	Intersects Tier 1 = 15 points Tier 2 = 10 points Tier 3 = 5 points Tier 4 = 1 point
Bridges and Culverts	10	Bridges and culverts provide a greater opportunity for improving existing infrastructure through retrofits or when they are replaced. Our Bridge and Culvert layer was filtered for only those that went over streams and waterways thus providing opportunities for protecting and restoring aquatic and terrestrial connectivity.	If the road segment contained a bridge or culvert = 10 points
Feasibility			
Land Use	10	The permeability of the landscape for wildlife movement is related to the naturalness and degree the landscape has been developed for humans. Land use is a surrogate for this.	Average of bisected and adjacent pixels has on average Developed Area of 40% or less = 10 pts More than 40% = 0 pts
Protected Areas	10	Land ownership is an important factor in potential for wildlife to use that area, constructability of wildlife crossing mitigation, and long-term use for a structure.	If the road segment bisected a protected areas or was adjacent to a protected area = 10 points
TOTAL SCORE	120 POINTS		

3.1.1 Transportation Criteria

There are four transportation criteria. The WVC hot spots represent the MSHP reported crashes with wildlife and the hot spot analysis conducted on the most recent five-year WVC dataset (refer to Section 2.3.2 for detailed methods). Segments in the 90th, 95th, and 99th percentile received 5, 10, and 20 points, respectively, while all other segments received no points. The other three transportation criteria include crash rates per year, severity of crashes, and proportion of crashes that are WVCs. These criteria are complementary to the WVC hot spots and were selected to emphasize hot spots with particularly high rates of WVC or high severity of crashes.

The rate of crashes, or crashes per 0.5-mile segment per year, identifies smaller, more isolated areas with high rates of WVCs. These locations may not be captured in the hot spot analysis because they are isolated from other areas with a high number of crashes. The maximum possible score for this criterion was 10. There were 57,578 segments, 84 percent of the total segments, that had no recorded crashes. The rate of crashes per 0.5-mile per year ranged from 0 to 2.4 with an average of 0.06 crashes per 0.5-mile. When excluding segments with no crashes, that average increases to 0.35. To calculate the criteria score, crashes per year for each 0.5-mile segment were standardized by multiplying that value by 4.17.

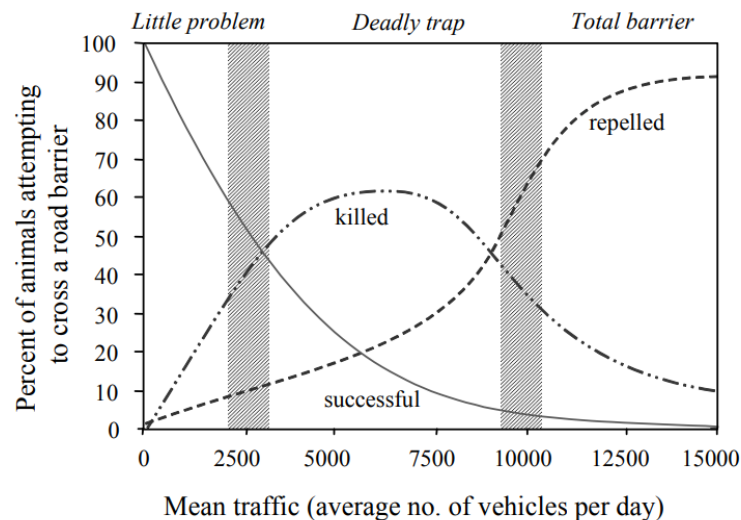
The locations of serious injury and fatal crashes were added to the scoring of every 0.5-mile segment. These were added to identify the most dangerous wildlife-vehicle crash locations in the state, which in turn could help MoDOT access national Highway Safety Improvement Program (HSIP) funds. The WVC dataset was filtered for only serious and fatal crashes. If one or more serious or fatal crash were present, that 0.5-mile segment received 10 points, and zero points if it did not have a serious or fatal crash. There were only 218 segments (0.3 percent of all segments) that received points under this criterion.

The proportion of all crashes that were wildlife-related was included to identify road segments that were particularly dangerous due to wildlife. Any segments with only one crash were removed. The proportion of wildlife-related crashes ranged from 0 to 100 percent with an average of 4.5 percent of wildlife-related crashes. The percentage was divided by 10 to result in possible scores between 0 and 10.

3.1.2 Ecological Criteria

The ecological data were selected to represent areas of the state where roads bisect or are adjacent to occupied and suitable habitat for priority species (**Section 2.5**), MDC CCS Management Tiers 1-4 (**Section 2.4**), and aquatic features where water flow is of great enough volume to require culverts and bridges. Additionally, traffic volume, represented by AADT as an ecological criterion, was included because it can be used as a surrogate for the permeability of roadways by wildlife (**Figure 3-1**, Seiler 2003).

Figure 3-1: Conceptual model on the effect of traffic volume on wildlife crossing success (Seiler 2003).



AADT ranged from 24 to 185,936. Segments with AADT greater than 10,000 received 10 points and segments with AADT between 2,000 and 10,000 received 5 points. Segments with AADT under 2,000 received 0 points. This approach adds additional weight to highways that are likely barriers to movement due to high traffic volume and for that reason may not be represented in WVC hot spots analyses but create barriers to wildlife connectivity. There were 12 percent of segments that received 10 points, 22 percent of segments received 5 points, and 66 percent received zero points.

Occupied habitat of priority species is an important indicator of the presence of these species, their vulnerability to the effects of roads, and the biodiversity richness of an area that any wildlife mitigation could help maintain and continue to restore. Occupied habitat layers were developed or obtained for each of the priority species identified for this project (**Section 2.5**), except white-tailed deer because they are ubiquitous. Data were obtained from many resources including the MDC Natural Heritage database occurrence data, federally designated habitat for the Niangua Darter and the Indiana bat, black bear habitat model (Gantchoff et al. 2022), and MDC elk telemetry data. The data sources used to represent each priority species are discussed in **Section 2.5.2.2**. The average score for occupied habitat was 2.6 points.

Suitable habitat represents areas important for priority species that may or may not be occupied. The Project team used USGS land cover mapping and MDC habitat association information for each priority species to map suitable habitat at a statewide scale. The methodology for creating these maps is discussed in **Section 2.5.2.1**. If a road segment intersected mapped suitable habitat for a priority species, the segment would score 0.5 points per species. The maximum score across all segments was 10 points; therefore, the total score was divided by 2 to stay under the maximum score of 5.

As discussed in **Section 2.4.2.1**, the MDC has established the Tiered Approach to Natural Community and Habitat Management, which is outlined in the MDC CCS plan. The Tiered approach identified areas with outstanding ecological value (Tier 1) to relatively poor ecological value (4). MDC Tier 1 through 4 landscapes were used to represent areas of elevated ecological value and a land management regime suitable to uses focused on wildlife mitigation. Road 0.5-mile segments that intersected Tier 1, 2, 3, and 4 lands received 15, 10, 5 and 1 point, respectively.

Finally, bridges and culverts were included to represent aquatic and riparian habitats which are often used as movement corridors for a wide variety of wildlife, including several priority species. The presence of bridges and culverts also represents opportunities to improve these features and provides a greater opportunity for improving existing infrastructure through retrofits or scheduled replacements. The bridge and culvert layer was filtered for only those that went over streams and waterways thus providing opportunities for protecting and restoring aquatic and terrestrial connectivity.

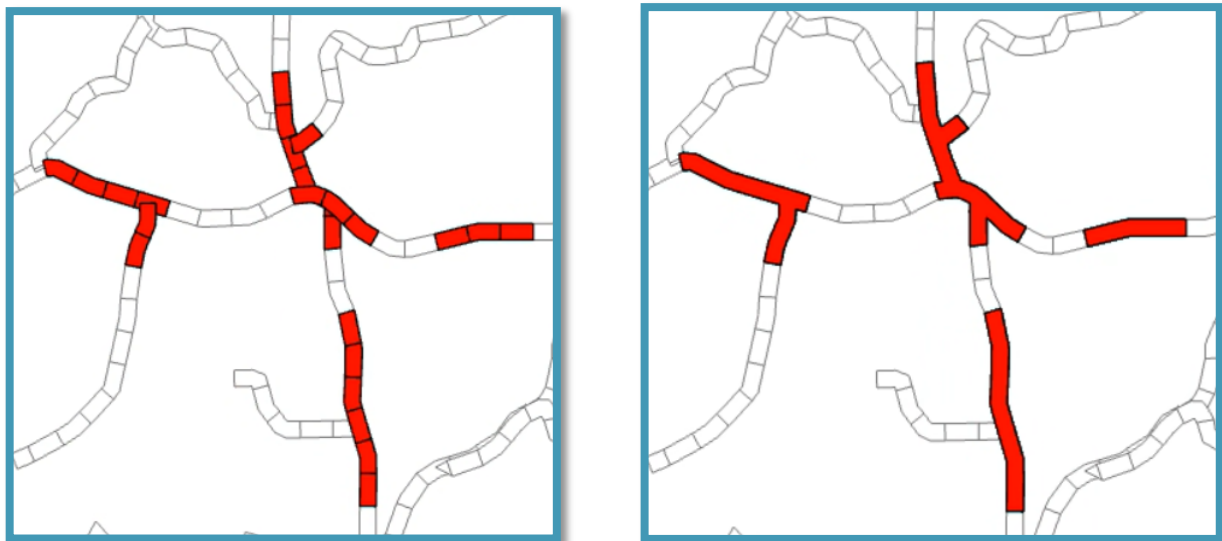
3.1.3 Feasibility Criteria

Feasibility was assessed by two criteria: land use and protected areas. These criteria are surrogates for land security and land acquisition for the construction of mitigation measures and the long-term condition of the surrounding landscape. State parks, wildlife areas, and other public lands are reasonably assumed to be free from future development or significant land use change. Therefore, areas with a higher proportion of currently undeveloped land cover types and protected areas would represent better opportunities for mitigation measures. The maximum score for each criteria was 10 points, and the average score for land use and protected areas was 6.6 and 1, respectively. This indicates that the majority of segments were 40 percent or less developed and approximately 10 percent of segments intersected a protected area.

3.1.4 Criteria Scoring

The maximum scores and scoring formulas were recommended by the project team and approved by the TAC. A maximum of 120 points was possible from all eleven criteria, including 50 each from transportation and ecological criteria and 20 total from feasibility criteria. Each segment (**Section 2.3.2**) was scored based on the formulas in **Table 3-1**. The scores from each criterion were summed within GIS to find the total score for each segment. The total scores for each segment were then run through the ArcGIS Pro OHSA tool, as was explained in **Section 2.3.2**, to identify hot spots of wildlife vehicle conflict. Segments identified through OHSA as occurring within the 99 percent confidence interval were considered priority segments and advanced for further analysis and prioritization, while the remaining segments were excluded. Priority segments that were adjacent to one another were aggregated to form a single priority segment, and their scores were averaged (**Figure 3-2**). This process identified 627 priority segments. The Top 100 ranking priority segments (Top 100) were carried forward for further analysis. Figures illustrating the priority segments and Top 100 across each MoDOT district are illustrated in **Appendix E**.

Figure 3-2: Aggregation of adjacent hot spots within the 99 percent confidence interval (Left: Pre-aggregation, Right: Post-aggregation).



3.2 Identification of Top 10 Segments

Three members of the Project team evaluated each of the Top 100 based on a qualitative assessment of land use, constructability, and funding in conjunction with the current State Transportation Improvement Program (STIP) (**Appendix F**). Google Earth was used to conduct the evaluation, making use of aerial imagery and Google Street View. In addition to the Top 100, the project team was provided a Google Earth file of all bridges and culverts. Each of the three criteria was rated on a 0 to 3 scale and the variance between each reviewer was compared. Any segment that had a variance of two or more for each of the three criteria was jointly evaluated and scores updated if deemed appropriate. The mean value of the three project team reviewers was used as the overall score for each criteria, and the mean of all three criteria (possible range from 0 to 3) was then used as the final review score to rank the Top 100 and identify the Top 10 wildlife vehicle conflict areas across the state of Missouri. The following three sections on land

use, constructability, and funding are provided below to further elucidate the factors that went into this final ranking.

3.2.1 Land Use

Land use was included because the land cover dataset can be outdated or inaccurate due to resolution and processing limitations. Land use was assessed as a qualitative surrogate for existing landscape fragmentation and permeability by wildlife. A visual assessment of land use based on aerial imagery, specifically the proportion of developed to undeveloped land, was conducted for each segment in adherence to the following rubric:

- 0 = 75-100 percent developed
- 1 = 50-74 percent developed, may be more developed if isolated
- 2 = 25-49 percent developed, may be more developed if isolated
- 3 = 0-24 percent developed, unrestricted

The larger landscape surrounding each Top 100 segment was also evaluated in terms of land use to identify the likelihood and importance for wildlife movement on a more landscape level or regional scale. If riparian areas and undeveloped/natural habitat formed linear features that could act as movement corridors on a landscape scale, the segment was considered for a higher score.

The type of land use was also a factor in consideration of scoring each segment. Commercial or industrial land uses were considered less conducive to wildlife movement than dispersed residential or agricultural land uses.

The presence of adjacent linear features such as frontage roads, railroads, and transmission lines was also considered. The presence of driveways and intersections was a negative consideration, as these would require double cattle guards or similar wildlife exclusion features that can increase construction and maintenance costs and may result in opposition from local residents due to noise and visual impacts.

3.2.2 Constructability

Constructability was included as an evaluation factor because most spatial data is insufficient in determining the suitability of a segment for construction of wildlife crossings. The topographic relief and terrain features were evaluated using aerial imagery and Google Street View. Areas with cut slopes on both sides of the road or areas with fill and embankments on both sides of the road were assumed to be suitable for overcrossings and undercrossings, respectively. Top 100 segments that included existing bridges and culverts were ranked higher, particularly when the existing culverts were large or the existing bridges had high vertical clearance. In general, constructability was ranked based on the following rubric:

- 0 = flat topography, no culverts or bridges
- 1 = somewhat suitable topography, low vertical clearance structures present
- 2 = suitable topography, structures present
- 3 = suitable topography, multiple structures with high vertical clearance present

3.2.3 Funding

The Top 100 were evaluated based on their inclusion in the STIP between 2025 and 2029 (MoDOT, 2025d). The STIP is a staged, multi-year, statewide intermodal program for transportation projects. Inclusion of a potential wildlife crossing project in the STIP greatly increases the potential for available funding but is dependent on the type of project in the program. The STIP projects were spatially joined to the Top 100 using ArcGIS Pro and ranked using the following rubric:

- 0 = not included in STIP or limited to pavement, pedestrian, etc.
- 1 = funds potentially available for fencing or small retrofits
- 2 = funds allocated for bridge rehabilitation, new road work
- 3 = funds allocated for culvert and/or bridge replacement

Some priority segments overlapped multiple STIP projects, in which case the highest possible STIP score was used for that segment.

3.2.4 Results

The top-ranking segments from the qualitative review process were discussed with the TAC on May 20, 2025, and additional scrutiny was given to each segment to determine the Top 10 segments (Top 10). The Top 10 were determined and named based on the nearest protected area (**Appendix G, Table 3-2**). Other Top 100 segments that were within close proximity and held similar criteria scores were considered a single Top 10 segment, but the gaps between them were excluded from future mitigation recommendations due to their low scores. This included the Four Rivers Conservation Area, Fox River and Buck Run, and Honey Creek Conservation Area, which each had two segments. The quantitative score ranking for the Top 10 is listed in **Table 3-3**.

Table 3-2: Top 10 Priority Segment Locations.

Rank	Name	MoDOT District	County	Road	Milepost Start	Milepost End
1	Pershing State Park	Northwest	Linn	US 36	83	95
2	Four Rivers Conservation Area (1) and (2)	Southwest	Vernon	IS-49	107	114
3	Wappapello Reservoir	Southeast	Wayne	MO-34	35	38
4	Whiteman Airforce Base and Knob Noster State Park	Kansas City	Johnson	RT-DD	4	8.5
5	Parma Woods Shooting Range	Kansas City	Platte	IS-435	0	4
6	Fox River and Buck Run (1)	Northeast	Clark	MO-27	0	1
6	Fox River and Buck Run (2)	Northeast	Lewis	US-61	374	377
7	Long Branch State Park	Northeast	Macon	US 36	122	124
8	Maramec Springs State Park	Central	Crawford	MO-8	6	8.5
9	Roubidoux Creek Conservation Area	Central	Pulaski	MO-17	139	141.5
10	Honey Creek Conservation Area (1) and (2)	Northwest	Holt	IS-29	70	74

Table 3-3: Prioritization Score Results for the Top 10 Segments.

Criteria	Four Rivers Conservation Area (1)	Four Rivers Conservation Area (2)	Fox River and Buck Run (1)	Fox River and Buck Run (2)	Honey Creek Conservation Area (1)	Honey Creek Conservation Area (2)	Long Branch State Park	Meramac State Park	Parma Woods State Park	Pershing State Park	Roubidoux Creek Conservation Area	Wappapello Reservoir	Whiteman Air Force Base and Knob Noster State Park
Wildlife-Vehicle Crash Hot Spot	10.0	10.5	20.0	11.4	20.0	20.0	18.8	16.3	20.0	14.0	12.0	8.0	20.0
Wildlife Crashes Per Segment Per year	1.4	1.6	3.3	1.8	1.9	4.2	2.2	2.3	3.0	1.4	1.8	1.2	2.4
Crashes with Fatality and/or Serious Injury	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	2.0	0.0	0.7
Percentage of All Crashes that are WVC	2.8	2.2	2.7	6.0	2.2	5.8	5.1	5.8	3.0	2.5	1.5	4.8	3.8
Transportation Score Total	14.2	14.3	26.0	19.2	24.2	29.9	26.0	24.4	26.6	17.9	17.3	13.9	26.9
Traffic Volume = AADT	10.0	9.5	5.0	10.0	10.0	10.0	10.0	0.0	7.4	9.0	5.0	5.0	5.0
Occupied Habitat	2.0	1.3	6.0	2.6	3.5	4.5	3.4	3.0	1.4	3.8	2.8	5.0	2.6
Suitable Habitat	3.8	4.2	4.8	3.9	3.8	4.1	3.9	4.3	3.9	3.6	4.0	4.0	3.3
MDC CCS Management Tiers	13.3	9.0	10.0	5.0	0.0	0.0	5.0	6.3	5.0	6.2	7.0	6.0	0.9
Bridges and Culverts	6.7	6.0	10.0	1.4	3.3	0.0	3.8	5.0	2.4	3.7	4.0	4.0	2.1
Ecological Score Total	35.8	30.0	35.8	22.9	20.6	18.6	26.1	18.6	20.0	26.2	22.8	24.0	14.0
Land Use	10.0	8.0	10.0	10.0	10.0	10.0	8.8	10.0	5.9	10.0	10.0	10.0	7.9
Protected Areas	6.7	6.0	0.0	7.1	0.0	0.0	2.5	10.0	2.4	2.8	10.0	10.0	7.9
Feasibility Score Total	16.7	14.0	10.0	17.1	10.0	10.0	11.3	20.0	8.2	12.8	20.0	20.0	15.7
Grand Total	66.7	58.3	71.8	59.2	54.7	58.6	63.3	62.9	54.8	56.9	60.1	57.9	56.6

(1)(2) – Segment names denoted with a 1 or 2 are part of the whole top 10 segment. There are three total top 10 segments with two parts.

4 Environmental Overview

An environmental review was completed for each of the Top 10 in order to identify potential impacts to known environmental resources that may require avoidance, impact minimization, or mitigation. This review also serves to support the alternatives analyses for potential improvements and future National Environmental Policy Act (NEPA) review documentation. Environmental resources reviewed for this effort included: land use, air quality, hazardous materials, noise sensitive receptors, visual environment, historic architectural and archaeological resources, terrestrial habitat, threatened and endangered species, Section 4(f) and Section 6(f) resources, floodplains, water quality, and wetlands and streams.

4.1 Land Use

The U.S. Department of Agriculture (USDA) NRCS has classified farmland soils into three categories based on suitability for agricultural uses. These include soils of prime, unique, and statewide importance. Criteria used for prime and unique farmlands was published January 31, 1978, in the Federal Register and amended on June 17, 1994 (7 CFR Part 657). The USDA NRCS has defined prime farmlands as soils that are best suited to producing crops, feed, forage, fiber, oil seed crops, and available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land, but not urban built-up land or water). These soils produce the highest yields with minimal inputs of energy and economic resources. Unique farmlands include soils that have a special set of properties that are unique for producing certain high value



crops. Farmland of statewide importance are lands that do not meet the requirements for prime farmland but that are of statewide importance for the production of food, feed, fiber, forage, and oil seed crops.

USDA NRCS (2025d) soil data was reviewed for each of the Top 10.

4.2 Air Quality

Air quality relating to emissions by stationary (such as electric power plants, steel mills, factories, and universities) and mobile sources of air pollution are regulated by the USEPA under the Clean Air Act. The Clean Air Act authorizes USEPA to set National Ambient Air Quality Standards (NAAQS) and mandates that states develop state implementation plans (SIPs) to outline how meeting NAAQS will be achieved.

The NEPAassist database was reviewed to identify permitted stationary sources of air pollution within the Top 10 USEPA 2025b).

4.3 Hazardous Materials

Hazardous materials are any materials that alone and/or when combined with other materials could have a negative effect on humans or the natural environment. These materials are often toxic, reactive, flammable, corrosive, or other such characteristics. They are primarily regulated by the Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA).

NEPAassist (USEPA 2025b) and the Missouri E-Start (MoDNR n.d.a) databases were reviewed to identify potential sources of hazardous materials within and adjacent to the Top 10.

4.4 Noise Sensitive Receptors

Noise is typically defined as undesired sound and/or sound that interferes with someone hearing something else. Common sounds such as traffic, air conditioners, and bird calls, are typical of urban and suburban areas; whereas sounds in rural areas are typically quiet or associated with agricultural equipment, farm animals, bird calls, etc. The Federal Noise Control Act of 1972 requires that all federal agencies promote environments that are free from noises that could impact human health or welfare. This is detailed in FHWA Noise Standard 23 CFR Part 722. MoDOT's Noise Policy constitutes procedures for meeting the federal requirements.

FEMA (2024) building data was reviewed to identify potential noise sensitive receptors within the Top 10.

4.5 Visual Environment

The FHWA requires that visual impacts of roadway projects be considered during project design, particularly in regard to other resources such as archaeological, historical architecture, wildlife, and Section 4(f) and 6(f) properties.

Desktop review of aerial imagery was used to describe the visual environment surrounding each of the Top 10.

4.6 Historic Architectural and Archaeological Resources

Section 106 of the National Historic Preservation Act (NHPA) and Section 4(f) of the Department of Transportation Act require that MoDOT consider the potential impacts that any federally funded or permitted project may pose to significant cultural resources. Cultural resources include archaeological sites, buildings, structures (e.g. bridges), objects, and districts. The significance of a cultural resource is evaluated by applying a set of criteria that are set forth by the National Register of Historic Places (NRHP). Cultural resources that meet the criteria of eligibility for listing or already listed are protected by the NHPA.

The regulatory process for archaeological historic resources is similar to architectural. Under Section 106 of NHPA, MoDOT is required to consult with Missouri State Historic Preservation Office (SHPO) on potential impacts to archaeological sites. Native American tribes whose historical range is within the Top 10 should also be consulted for any concerns regarding tribal sites.

Missouri SHPO (MoDNR n.d.b) and the NPS (2025) NRHP GIS Public Dataset were reviewed for historical cultural and architectural resources within the Top 10.

4.7 Terrestrial Habitat

There are no federal regulations that specifically protect terrestrial habitat, but there are certain areas of habitat designated as critical habitat by the USFWS for species listed under the ESA (Section 4.8). NRCS developed Ecological Site Descriptions to characterize the vegetation and soils of the United States (USDA 2025a). Ecological Site Descriptions are grouped by Major Land Resource Areas.

4.8 Threatened and Endangered Species

The ESA is managed by USFWS and was enacted to protect species of concern from extinction. USFWS uses a digital project planning tool known as the IPaC, which identifies federally listed species and designated critical habitat that may occur within or in proximity to the Top 10 (USFWS 2025a).

4.8.1 Federally Listed Species

Federally listed species are classified as endangered or threatened, and species in review for federal listing are classified as proposed endangered, proposed threatened, or candidate. Endangered species are at risk of extinction throughout all or a significant portion of their range. Threatened species are likely to become endangered within the foreseeable future throughout all or a significant portion of their range. Threatened and endangered species are protected by the take prohibitions of Section 9 under the ESA. Species listed as proposed endangered include any species the USFWS has determined is in danger of extinction throughout all or a significant portion of its range and the USFWS has proposed a draft rule to list as endangered. Proposed threatened species include those that the USFWS deems likely to become endangered within the foreseeable future throughout all or a significant portion of their range and the USFWS has proposed a draft rule to list as threatened. Proposed threatened and proposed endangered species are not protected by the take prohibition of Section 9 of the ESA until the rule to list is finalized. Under Section (7)(a)(4) of the ESA, federal agencies must confer with the USFWS if their action will



jeopardize the continued existence of a proposed species. Species with candidate status include any species for which there is sufficient information on their biological status and threats to propose them as endangered or threatened in the ESA, but for which development of a proposed listing regulation is precluded by other higher priority listing activities. Candidate and proposed-listing species are not protected by the take prohibitions of Section 9 of the ESA.

4.8.2 State Listed Species

MDC maintains a list of threatened and endangered species pursuant to the Revised Statutes of Missouri RSMo Section 252.240 and the Missouri Wildlife Code. These statutes ban the "importation, transportation, or sale of any endangered species of fish or wildlife, or hides or other parts thereof" (RSMo § 252.240. 1984). The Wildlife Code outlines hunting and fishing regulations and permit requirements, as well as processes should violations of the Code occur.

The MDC county list of threatened and endangered species (MDC 2025a) was reviewed to identify state listed species with the potential to occur within the Top 10.

4.8.3 Eagles

The Bald and Golden Eagle Protection Act (BGEPA) [16 USC § 668–668(c)] prohibits anyone, without a permit issued by the Secretary of the Interior, from "taking" bald or golden eagles, including their parts, nests, or eggs.

IPaC was used to determine if bald or golden eagles have the potential to occur within the Top 10 (USFWS 2025a).

4.8.4 Migratory Birds

The MBTA of 1918 prohibits the "take" of migratory birds. The regulatory definition of "take" as defined by 50 CFR § 10.12, "means to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue hunt, shoot, wound, kill, trap, capture, or collect." The following prohibitions apply to migratory bird nests: "possession, sale, purchase, barter, transport, import and export, take, and collect." The MBTA is enforced by the USFWS.

IPaC was used to determine if migratory birds have the potential to occur within the Top 10 (USFWS 2025a).

4.9 Section 4(f) and Section 6(f) Resources

Section 4(f) of the U.S. Department of Transportation Act protects historic properties and publicly owned parks, recreational land, and wildlife and waterfowl refuges from conversion to transportation uses. Any federally funded project must comply with Section 4(f).

Section 6(f) of the Land and Water Conservation Fund (LWCF) Program protects lands and facilities acquired with LWCF funds.

PAD-US (USGS GAP 2024) data was reviewed to determine if Section 4(f) resources occur within the Top 10. The LWCF (2025) database was similarly reviewed for the presence of Section 6(f) resources.

4.10 Floodplains

Agencies are required to reduce the risk of impact to floodplains and main channel flow (floodway). Floodplain protection is required under several federal, state, and local laws, including Executive Order 11988 entitled "Floodplain Management," which requires avoidance of modifications to and supporting development in floodplains. Floodplains subject to inundation by the 1-percent-annual-chance flood event are regulated by FEMA. Any project in a floodway must be reviewed to determine if the project will increase flood heights. An engineering analysis must be conducted before a permit can be issued.

FEMA Flood Hazard data was reviewed to determine the presence of floodplains within the Top 10 (FEMA 2024).

4.11 Water Quality

The USEPA maintains a list of impaired waters through the Clean Water Act (CWA) Section 303(d). Impaired waters are defined as waters that are impaired or threatened with impairment and require a Total Maximum Daily Load (TMDL) restoration plan, which defines the maximum amount of a pollutant a waterbody can contain and still meet water quality standard.

The Section 303(d) database was used to identify any impaired waters within the Top 10 (USEPA 2025a).

4.12 Wetlands and Streams

Waters of the United States (WOTUS) and adjacent wetlands are protected under the CWA. WOTUS is the encompassing term for areas that qualify for federal regulation under Section 404 of the CWA. The CWA gives the USEPA and the USACE regulatory and permitting authority over WOTUS. Impacts to WOTUS require a Section 404 permit. MoDNR also has jurisdiction over WOTUS in Missouri, and their regulatory authority derives from Section 401 of the CWA. A Section 401 Water Quality Certification (WQC) is required whenever a project needs a federal permit that may result in impacts to WOTUS.

The USFWS (2024b) NWI, USGS (2023a) NHD, and aerial imagery were referenced to determine the presence of streams and wetlands throughout the Top 10.

4.13 Socioeconomic Factors

Socioeconomic information reviewed for the Top 10 included limited English proficiency populations; minorities; Area of Persistent Poverty (APP) (defined as: (1) any county that has consistently had greater than or equal to 20 percent of the population living in poverty during the 30-year period proceeding November 21, 2021, as measured by the 1990 and 2000 decennial censuses and the most recent annual Small Area Income Poverty Estimates as estimated by the U.S. Census Bureau (USCB); (2) any census tract with a poverty rate of at least 20 percent as measured by the 2014-2018 5-year data series available from the American Community Survey of the USCB, or (3) any territory or possession of the United States); Historically Disadvantaged Communities (defined to include (1) certain qualifying census tracts identified by the Climate and Economic Justice Screening Tool as disadvantaged due to categories of environmental, climate,



and socioeconomic burdens, and (2) any Federally Recognized Tribes or Tribal entities, whether or not they have land); low-income; and minority-owned businesses in and around the Top 10.

The USCB maintains demographic and socioeconomic information on populations and businesses throughout the United States. The U.S. Department of Transportation (USDOT) collects information on Areas of Persistent Poverty and Historically Disadvantaged Communities by Census Tract (CT) and county as part of the Multimodal Project Discretionary Grant program.

The USCB (2025) data, USDOT Multimodal Project Discretionary Grant (2024) data, and an archived version of the Climate and Economic Justice Screening Tool (2024) were used to review demographic and socioeconomic data for the Top 10.

4.14 Summary of Environmental Resources

An overview of environmental resources present and the potential for impacts from mitigation projects within the Top 10 is provided below (**Table 4-1**). Each site is discussed in further detail in **Appendix H**.

Table 4-1: Potential Impacts to Known Environmental Resources within the Top 10

Resource	Impact Potential by Segment ^a									
	Pershing	Four Rivers	Wappapello	Whiteman Airforce Base	Parma Woods	Fox River / Buck Run	Long Branch	Maramec Springs	Roubidoux Creek	Honey Creek
Land Use	H	H	M	M	M	H	M	M	L	M
Air Quality	L	L	L	L	L	L	L	L	M	L
Hazardous Material	M	L	M	H	M	M	L	M	M	L
Noise	H	M	M	H	H	M	M	L	M	L
Visual Environment	H	H	H	H	H	M	M	M	H	M
Architectural and Archaeological	M	L	H	H	H	H	M	H	H	M
Terrestrial Habitat	L	L	H	L	L	L	L	H	H	L
Federal and State Listed Species	H	H	H	H	H	H	H	H	H	H
Section 4(f) and 6(f)	H	H	H	H	H	L	L	H	H	L
Floodplains	H	H	H	H	H	H	H	H	H	H
Water Quality	H	L	L	H	L	H	L	L	H	M
Wetlands and Streams	H	H	H	H	H	H	H	H	H	H
Socioeconomic Factors	L	H	M	M	M	L	L	M	M	L

^a H: High chance of impact - Multiple resources exist within the segment. M: Moderate chance of impact - A few resources exist within the segment. L: Low to no chance of impact - Little or no resources exist within the segment.

5 Future Conditions

5.1 Human Population Growth

Missouri's overall population has grown modestly from approximately 6.15 million in 2020 to 6.24 million in 2024, an increase of about 1.5 percent (USCB 2024). This places Missouri in the middle of growth trends among its neighboring states. Arkansas and Oklahoma outpaced Missouri, each growing by approximately 2.5–3.5 percent, driven by higher in-migration and younger populations. Nebraska and Iowa also saw moderate gains of around 2 percent, supported by a mix of urban and agricultural stability. In contrast, Kansas experienced relatively stagnant growth (1 percent increase), while Illinois notably declined in population, losing roughly 1 percent during the same period, largely due to net domestic out-migration. Overall, Missouri's growth is steady but lagging behind more dynamic neighbors, particularly in areas benefiting from stronger economic and housing trends.

From 2019 to 2023, Missouri's metropolitan areas (containing a core urban area of at least 50,000 residents) such as Kansas City, Springfield, Columbia, and Joplin demonstrated steady to strong growth, as shown in **Table 5-1** (USCB 2019; USCB 2023e). These areas are projected to continue growing significantly over the next two decades, with Kansas City potentially adding over 136,000 new residents by 2048. In contrast, smaller, urban areas show minimal growth. Population trends in communities like Hannibal, Rolla, and Sedalia remain relatively flat.

Table 5-1: City population growth trends in Missouri

Major Cities	Historical		Percentage Growth	Projections		
	2019 ^a	2023 ^b		2028	2038	2048
Urban						
St. Louis	308,174	293,109	-4.89%	274,278	236,615	198,953
Kansas City	486,404	508,233	4.49%	535,519	590,092	644,664
Springfield	167,051	169,432	1.43%	172,408	178,361	184,313
Columbia	121,230	127,200	4.92%	134,663	149,588	164,513
Joplin	50,386	52,218	3.64%	54,508	59,088	63,668
Jefferson City	42,919	42,565	-0.83%	42,123	41,238	40,353
St. Joseph	75,913	71,542	-5.76%	66,078	55,151	44,223
Rural						
Rolla	20,169	20,144	-0.12%	20,113	20,050	19,988
Sedalia	21,633	21,869	1.09%	22,164	22,754	23,344
Hannibal	17,320	16,825	-2.86%	16,206	14,969	13,731

^a USCB 2019; ^bUSCB 2023e

Growth dynamics in Missouri vary significantly between metro and nonmetro areas. Metro areas grew at an annual rate of 0.2 percent, with suburban counties such as Lincoln and Webster showing growth rates of 2.6 percent and 2.1 percent, respectively (MU Extension 2024). In contrast, nonmetro areas grew slightly faster at an annual rate of 0.3 percent, particularly in the southwest region, while areas like the Bootheel and northern counties experienced population declines. Economic dependencies (Mining, Manufacturing, Farming, Recreation, Government, and Diversified) played a crucial role in shaping population trends. Counties dependent on recreation saw the highest growth rate at 1.1 percent, driven by the rise of remote work and retirements. Farm and manufacturing-dependent counties also recorded population gains, whereas mining-dependent counties continued to see declines. The increase in remote work options significantly influenced suburban growth, helping to offset population declines in larger urban counties such as St. Louis County. This shift reflects broader post-pandemic trends in the U.S. economy, indicating ongoing changes in urban and rural population dynamics.

5.2 Traffic Conditions

Missouri's projected traffic growth trends are consistent with national forecasts and established state-level practices. According to the FHWA's Spring 2024 national projections, total vehicle miles traveled in the U.S. is expected to grow by approximately 0.6 percent annually through 2040, with light-duty vehicles increasing by 0.4 to 0.5 percent per year (FHWA 2024). In contrast, freight traffic is expected to grow at a faster pace, with single-unit trucks increasing by 1.9 to 2.1 percent annually, and combination trucks by 1.1 to 1.3 percent. MoDOT commonly applies a 0.5 to 1 percent annual growth factor for long-range traffic projections, particularly in non-metropolitan areas.

MoDOT focuses on maintaining and improving the condition of state highways. As of year-end 2023, 89.9 percent of major highways are in good condition, slightly below the target of 90 percent, while minor highways exceed the 80 percent target. Low-volume highways have seen significant improvement, reaching 78.6 percent, surpassing the 70 percent target (MoDOT 2025i). Since 2019, Missouri's STIPs have prioritized investments in paved road infrastructure, allocating substantial funding toward resurfacing interstates, major and minor routes, while also expanding focus areas such as rural low-volume roads (MoDOT 2025q). The 2020–2024 STIP allocated an average of \$924 million annually to resurface over 5,000 miles of interstate, major, and minor routes. This effort continued with the 2022–2026 STIP and expanded further in the 2023–2027 STIP, which introduced \$10 billion in funding, including \$100 million for rural low-volume roads. The most recent 2025–2029 STIP set a record with a \$14.6 billion program, dedicating \$10.7 billion to road and bridge projects, supported by state general revenue and focusing on key corridors like Interstate (IS)-70, IS-44, and rural routes. Beginning in fiscal year 2023, Missouri committed \$100 million annually from general revenue to the Rural Routes Program, a targeted initiative to rehabilitate low-volume rural roads across the state. The program addressed nearly 5,500 low-volume lane-miles since 2023 (MoDOT 2025k).

5.3 Climate Change

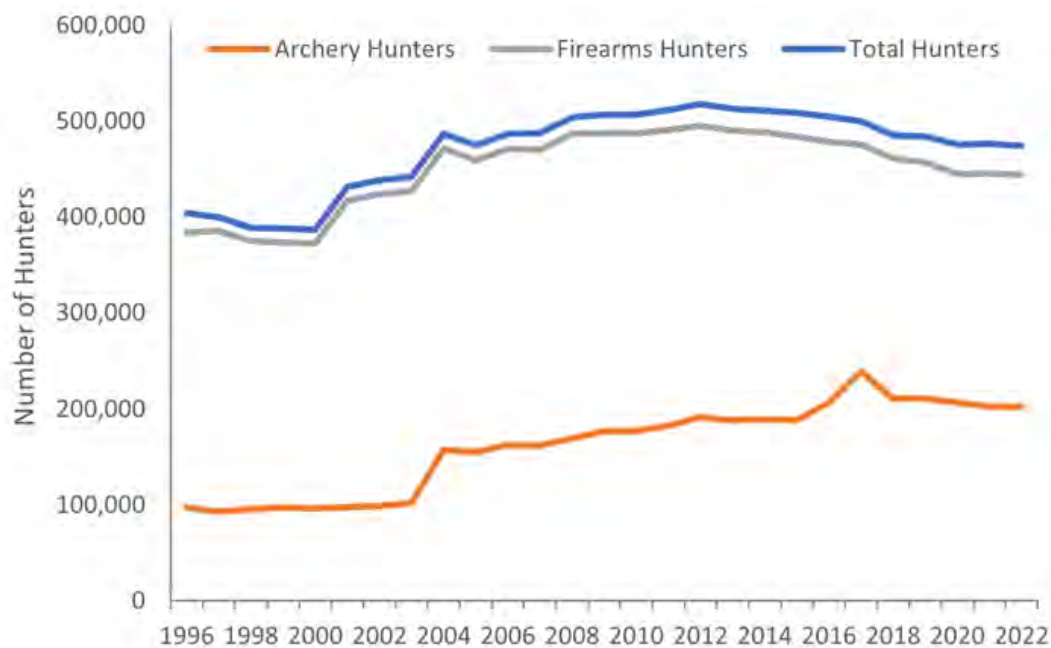
Missouri and the broader Midwest region are increasingly facing climate-related challenges such as extreme precipitation, more frequent freeze-thaw cycles, and flooding (Wilson et al. 2023).

These conditions significantly strain transportation infrastructure. While Missouri does not yet have a standalone climate adaptation guide, MoDOT's Engineering Policy Guide and asset management practices already incorporate elements of climate resilience. Regional studies emphasize the growing need to integrate climate risks into infrastructure planning, particularly for culverts, bridges, and pavement (Posey 2012). For traffic, this means prioritizing design strategies like oversizing drainage structures to handle extreme weather, updating materials to resist freeze-thaw damage, and incorporating dual-function elements that also support wildlife passage. Embedding these practices into project development and maintenance planning, especially in vulnerable and underserved communities, can enhance long-term infrastructure resilience and align evolving national resilience and equity goals.

5.4 Projected Focal Species Movement and Population

The MDC focal species for this study, white-tailed deer, elk, and American black bear, have varying population trends and projections. The spatial ecology and background for these species were previously discussed in **Section 2.5.1.5**. White-tailed deer remain ubiquitous across the landscape, with an MDC estimated population of 1.7 million in 2025. The population grew by 300,000 animals, or 21 percent since 2022 (MDC 2025b). As with many other mammals such as raccoons, coyotes, opossums, white-tailed deer are finding refuge within urban areas. With the human population in Missouri steadily increasing, white-tailed deer will continue to need to find refuge in urban areas. Cities such as Columbia, Jefferson City, Kansas City, and Springfield have urban archery hunting programs to help combat the increasing white-tailed deer populations. Hunter numbers have steadily declined in Missouri since 2012; the continuation of current trends would decrease the effectiveness of the urban hunting programs (MDC 2022c).

Figure 5-1: Trends in archery, firearms, and total deer hunter numbers in Missouri, 1996-2022 (MDC 2022c).



Chronic wasting disease is an emerging infectious disease that is fatal to both captive and wild deer. In Missouri, the disease was first detected in a wild deer herd in 2012. MDC conducts annual testing to monitor the spread of this disease, which has the potential to decimate the population (MDC 2022c). If white-tailed deer populations continue to increase, chronic wasting disease transmission rates may also increase. In the 5-10-20 year planning horizon, it is unclear how significantly the white-tailed deer populations may change given the multitude of variables, such as chronic wasting disease, climate change, land use, and hunter harvest, that impact carrying capacity.

MDC plans to grow the elk population in Missouri up to 500 head and restrict the herd to the Carter, Reynolds, and Shannon tri-county area known as the “Elk Restoration Zone” (**Figure 5-2**). Elk sightings do occur statewide, particularly in the northern region of Missouri as individuals cross over from a Nebraska herd. The population in Missouri is primarily controlled through a hunting season which began in 2020, but the public are encouraged to contact MDC with any nuisance problems. Overall, elk movement and population size in Missouri may increase (MDC 2020b).

Figure 5-2: MDC Elk Restoration Management Zone (MDC 2020b).



As noted in **Section 2.5.1.5**, American black bear populations continue to increase and expand northward from their source population in the Ozark region of Arkansas and southern Missouri. As of 2023, MDC estimated the population to be 900 individuals with an annual growth rate of 8 percent (MDC 2023). As a result, sightings in Missouri have continued to increase from less than 50 sightings in 2007 to more than 300 sightings in 2023. Gantchoff et al. characterized black bear habitat patch utilization across Missouri (**Figure 5-3**), which closely aligns with reported sightings (**Figure 5-4**). Habitat patches for black bears would only change as humans continue to develop

forested areas, specifically within riparian corridors. With population growth in rural areas being stagnant or reducing, movement corridors for black bear are less likely to be impacted. MDC management goals for American black bear do not include limiting their population but will continue to utilize a hunting season and annual quota to harvest a sustainable number from the population. Unless management of the species changes, the population is expected to continue to rise until carrying capacity is met.

Figure 5-3: American black bear core habitat, marginal, and highly marginal patches (Gantchoff et al. 2022).

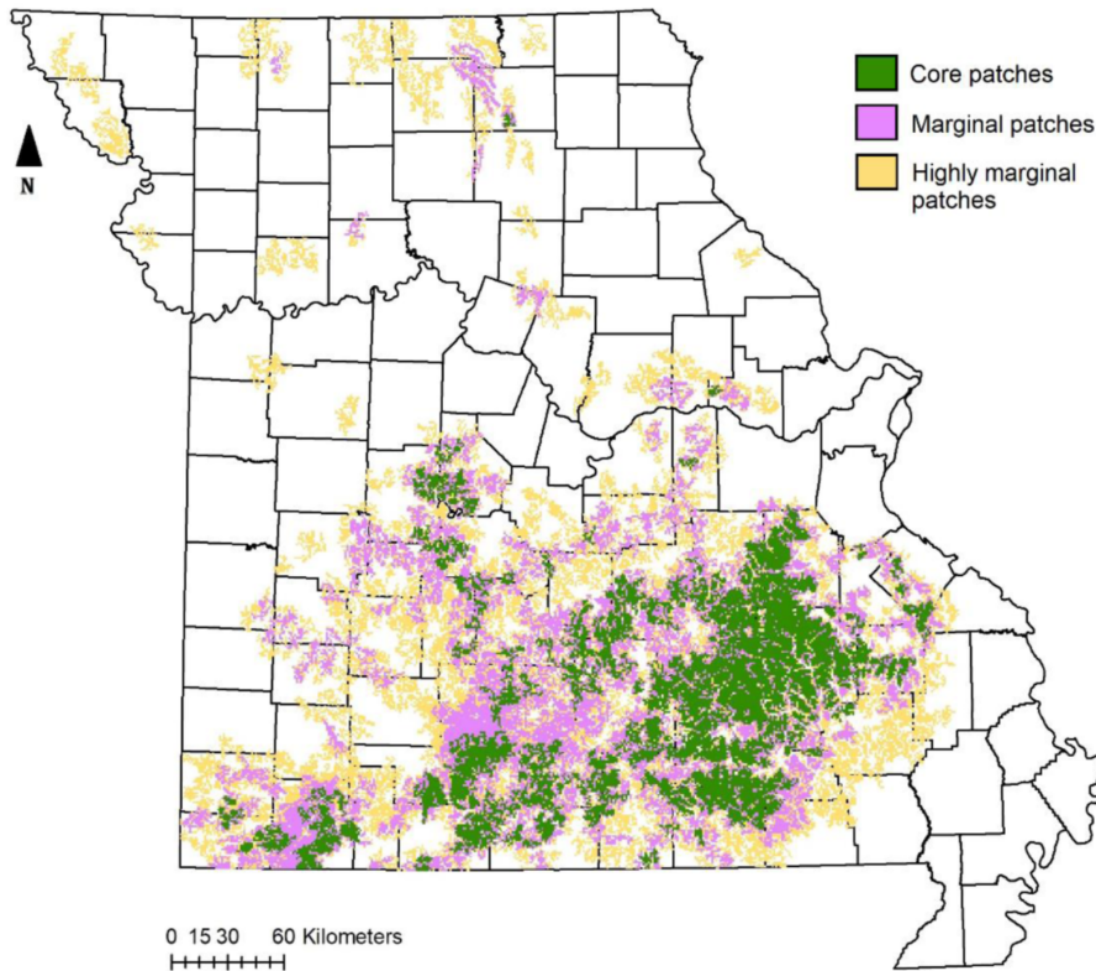
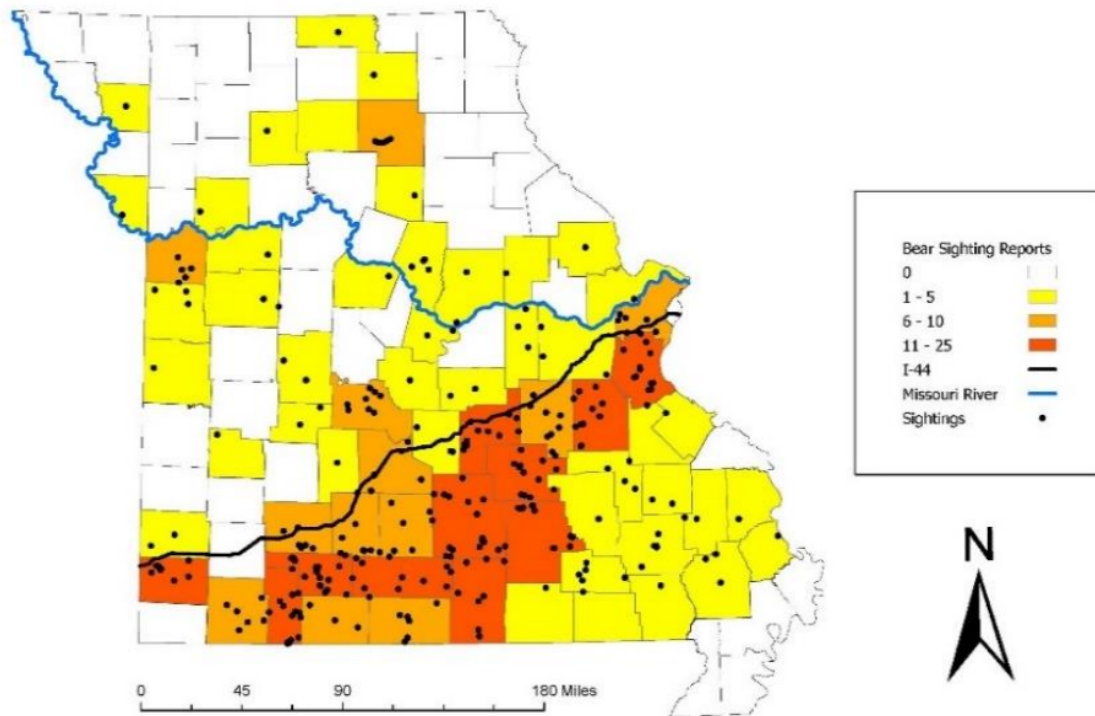


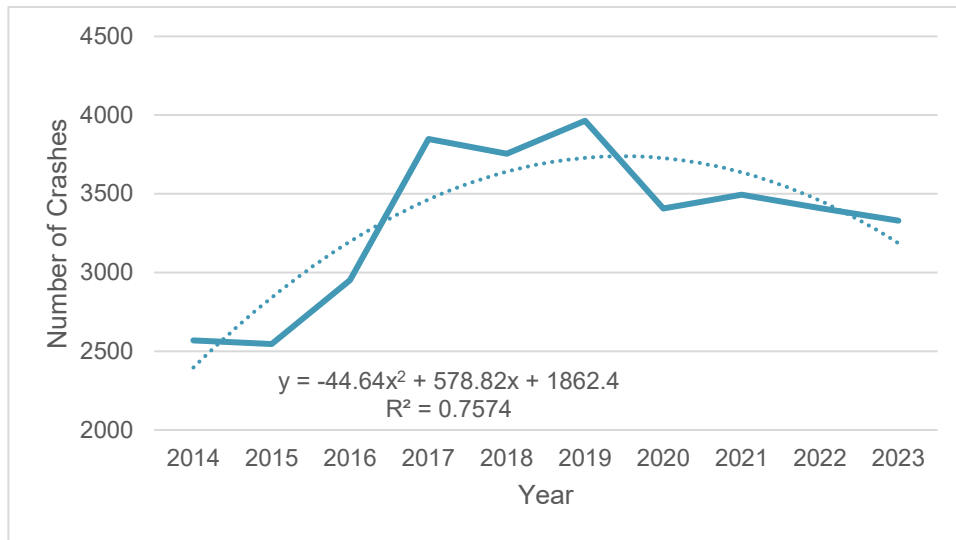
Figure 5-4: American black bear sightings by county in 2023. The black line represents Interstate 44 (MDC 2023).



5.5 Projected Wildlife Vehicle Conflict

According to the 2014 to 2023 MSHP wildlife crash dataset, reported WVCs were lowest in 2014 and peaked in 2019 (**Figure 5-5**). A quadratic regression model best fit the data ($r^2 = 0.75$) and illustrates the increase in collisions from 2014 to 2019 but shows a steady decline from 2019 to 2023. With human and deer populations increasing, it is unlikely that WVCs will follow this trend line and continue to decrease. A more robust dataset is necessary to project WVCs. These numbers are predominately influenced by white-tailed deer and do not account for growing populations of other large mammal species in Missouri, such as American black bear. Data provided by MDC shows 60 bear collisions since 2011 and an increasing number of road sightings. While total population size is insignificant compared to the estimated 1.7 million white-tailed deer in Missouri, collisions with black bears are expected to increase. Vehicle collisions with elk have been reported but no dataset was available. MDC noted these collisions have occurred predominately in the northwest of Missouri where elk herds in Nebraska migrate into Missouri. With introduced elk populations being managed within a tri county area that has a relatively low human population, it is unlikely for elk-vehicle collisions to significantly increase.

Figure 5-5: Number of Wildlife Vehicle Crashes from 2014 to 2023 and a quadratic regression estimate of future collisions (dotted line).



Unreported WVCs for Study priority species is a major gap in the available datasets and makes an understanding of both present and future conditions difficult. MoDOT customer service calls for carcass removal provide some data on WVCs, but this dataset is biased towards small to large mammals. To alleviate some of this bias, MoDOT developed a phone application to allow the public to report carcasses on roadways, in order to begin collecting this valuable data for future research.

As traffic volumes increase, so will the associated barrier effect of roadways, as discussed previously in **Section 3.1.2**. The resulting increase in habitat fragmentation may further isolate wildlife populations and reduce genetic diversity, placing SOCCs at greater risk of extirpation.

5.6 Summary of Future Conditional Needs and Risks

The transportation planning process can be adapted to incorporate the results of this Study in long-term transportation plans, in selecting STIP projects, and in planning for standalone wildlife mitigation and accommodations. With the expected increases in human populations in Missouri, especially within the cities of Kansas City, Jefferson City, Columbia, and Springfield, and the increasing populations of white-tailed deer, elk, and black bear, it is important Missouri plan for and construct wildlife mitigation and accommodations to reduce the risks of WVCs for motorists and provide connectivity for wildlife.

Between MoDOT's Rural Routes Program, which is contributing millions of dollars to upgrade rural roads, and the preparedness for climate resilience with replacing water conveyance structures such as culverts with larger infrastructure, there are continuous opportunities to include accommodations for wildlife movement beneath the roads. The planning for these accommodations can become part of everyday transportation processes, from long-term planning to maintenance. Selection of highly important projects can be guided by the results of this study.

The Top 10 priority segments identified in **Section 3.2.4** represent the highest priority locations in the state based on the evaluation approach defined and implemented by the project team with advisement from the TAC. These Top 10 locations are based on current conditions and currently available data, and they represent existing wildlife-vehicle conflict. These Top 10 locations should be prioritized for mitigation measures. However, it is possible that in the near-term, land use, land ownership, and funding availability may change the conditions at any of these Top 10 locations. Planning for mitigation measures should be adaptable in response to these changing factors. Supplemental information provided in support of this study is available to evaluate other highway segments should changes to the Top 10 preclude their inclusion in the future.

Over the long-term, land use and land ownership may change in addition to the environmental conditions and wildlife habitat use at each location as a result of various dynamic factors such as climate change, development, sprawl, wildfire or other natural perturbations. In addition, socio-economic, political, and various other emerging human factors may impact the severity of WVCs for wildlife. Factors such as the increasing popularity of electric vehicles, which typically have quieter engines that may be difficult for wildlife to hear, or auto manufacturing trends towards heavier vehicles may change the conditions of the roadway such that current issues are resolved, changed, or are exacerbated. As such, the results of this study do have a shelf-life and the study can be replicated, with appropriate modifications, in the future. Generally, we would not expect conditions to change within ten years, such that our results are outdated. Beyond ten years, the above factors may result in changes to our results.

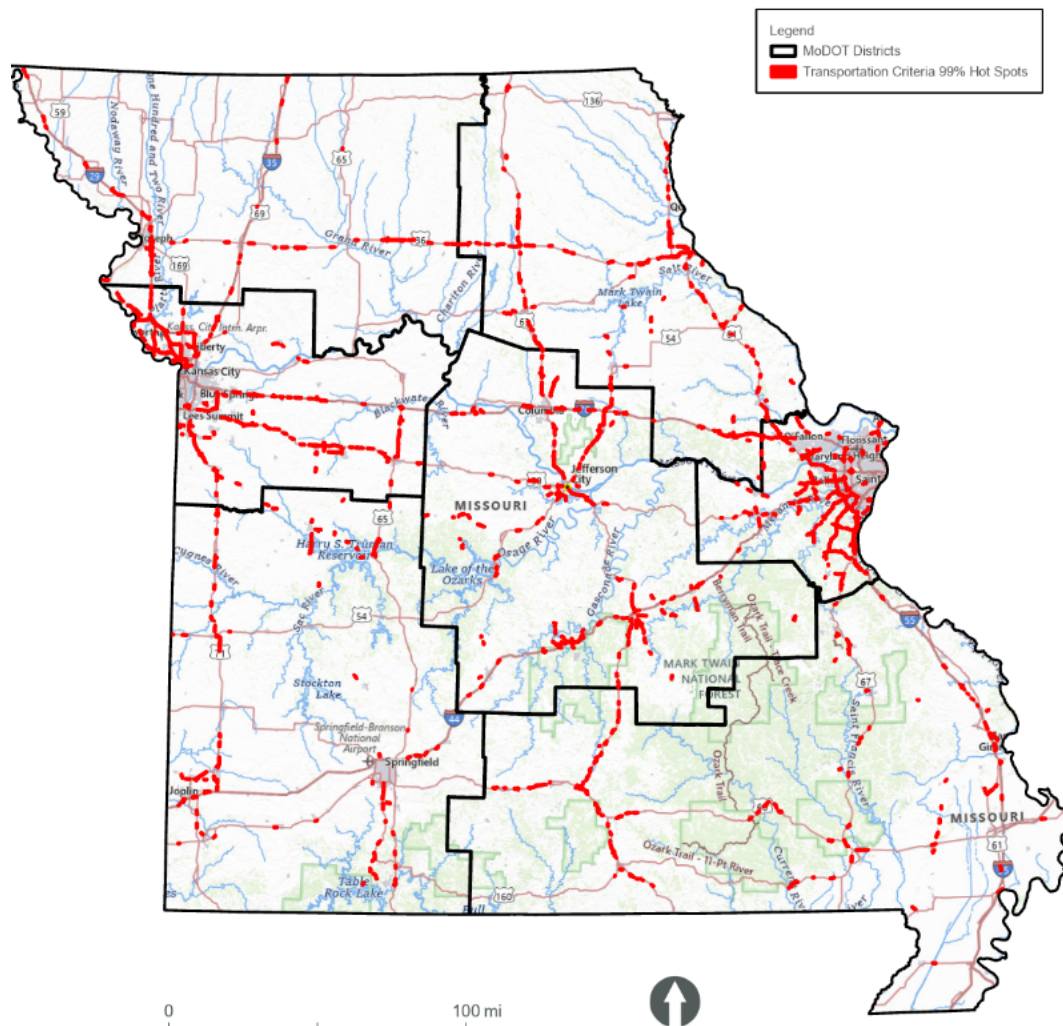
5.7 MoDOT Long Range Transportation Planning Process

MoDOT utilizes Transportation Management Systems (TMS) to visualize a multitude of transportation data such as traffic volume, crashes, environmental compliance, and infrastructure. The system was implemented in 1998 and is comprised of applications, reports, and maps. TMS is already used in the MoDOT transportation planning process, and the incorporation of geospatial results from this Study into TMS would allow immediate access across all MoDOT staff.

With MoDOT's primary goal of safety, it is recommended that the transportation safety criteria factors from this study be included within TMS to flag locations at high risk for WVCs. To accomplish this, the transportation criteria total from the prioritization analysis was run through the OHSA tool in ArcGIS Pro using a 0.5-mile distance band. Hot spots with a 99 percent confidence interval were carried forward and aggregated, if applicable, as done previously in **Section 3.1.4**. The resulting transportation criteria priority segments can then be included as a layer within a map or spatially joined to other layers such as road centerlines (**Figure 5-6**).

The Top 100 from **Section 3.1.4** should also be included as a layer or field within TMS to convey areas that have both an ecological benefit and are also feasible for wildlife vehicle conflict mitigation. With these layers available on TMS, MoDOT can incorporate it into the checklist for prioritizing infrastructure projects. Incorporating WVC mitigation into programs such as STIP is vital for ensuring projects are implemented.

Figure 5-6: Transportation Criteria Priority Segments.



Another method for implementing the results of this Study into the planning process is to include it in existing environmental review procedures. Before completing a project, MoDOT environmental staff complete a Request for Environmental Services (RES) to review potential impacts to the environment and the necessary permits and clearances that may be required. Adding a section into the RES form to check if a project is within a transportation or priority hot spot will flag the project for the MoDOT engineer to consider mitigation measures for WVCs.

Locating and applying for transportation funding is a critical step after identifying projects within priority locations. This study incorporated STIP funds into its prioritization, but there are other potential funding sources available to wildlife agencies and their partners, including grants through the Association of Fish and Wildlife Agencies. Other possible funding sources include:

- WCPP, which may become the Wildlife Road Crossings in later Transportation Acts
- Bridge Investment Program (BIP)



- National Culvert Removal, Replacement, and Restoration Grant Program (Culvert Aquatic Organism Passage [AOP])
- Nationally Significant Multimodal Freight and Highway Projects (INFRA)
- Nationally Significant Federal Lands and Tribal Projects (NSFLTP)
- Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT)
- Better Utilizing Investments to Leverage Development (BUILD)
- Rural Surface Transportation Grant Program

With changes in the federal administration, funding opportunities are consistently in flux, so it is important to check on the availability of these discretionary grant programs (Callahan et al. 2024). Another possible source of funding is partnering with organizations such as MDC to improve terrestrial and aquatic passage across MoDOT operated roads. This would help both agencies work towards their respective missions. Incorporation of the results from this study, along with obtaining funding through various sources, is paramount for implementing mitigation measures across the state.

6 Alternatives Analysis and Recommended Improvements

Wildlife mitigation strategy recommendations were developed for each of the Top 10 following site visits conducted in July 2025. The recommendations for the Top 10 were developed by combining the transportation, ecological, and feasibility factors data outlined in **Table 3-3** with observations recorded during the site visits and commonly used approaches to WVCs mitigation, discussed in **Appendix A**. These factors were synthesized to summarize conditions on the landscape for each of the Top 10 and to determine a cost-effective approach to protecting motorists by reducing the number of reported WVCs and maintaining or restoring habitat connectivity by utilizing existing bridges and culverts or by adding new structures. Priority actions were those that retrofit existing bridges and culverts with wildlife exclusion fences to guide wildlife to the structures, as well as short-term daily operations and maintenance actions, such as vegetation trimming and static sign placement. The resulting list of mitigation measure recommendations and accompanying benefit-cost analysis for each of the Top 10 will assist MoDOT in evaluating how the Top 10 could be mitigated to reduce WVCs, protect ecological connectivity, and ultimately make the Missouri state highway system safer for motorists.

6.1 Methodology

Each of the Top 10 were evaluated for mitigation opportunities using the information presented in previous sections, including crash and AADT data, MDC suitable and occupied habitat data for priority species, MDC CCS Management Tiers, the locations of streams, land use and ownership of lands adjacent to the segment, the locations of bridges and culverts, the constructability of new structure placements, and the locations relative to upcoming STIP projects.

Site-specific characteristics were also considered when identifying mitigation measures. Wildlife exclusion fencing placement and configuration recommendations were informed by the presence



of priority species within a segment in order to effectively guide animals to existing bridges. The land uses, neighbors, traffic volume, land protection status, and other factors all played additional roles in fencing recommendations, including determining fencing length and if mitigation was necessary given the set of conditions. Efforts were made to incorporate the recommended mitigation measures such as fences into upcoming STIP projects in the vicinity of the Top 10.

Likewise, the presence of water was critical to these analyses. The majority of the Top 10 were immediately adjacent to streams and rivers, and their associated riparian forests. The presence of existing bridges and culverts within the Top 10 allows for the addition of wildlife fencing, making these existing structures de facto wildlife crossing structures with little cost to MoDOT. Each of the Top 10 contained at least one bridge that could be retrofit with wildlife exclusion fencing to increase wildlife movement beneath the road and help reduce WVCs. Riparian forests near these water bodies are unlikely to be developed, thus wildlife use of the structure from both sides of the highway would likely continue.

The landscape surrounding each of the Top 10 was also important, particularly regarding mitigation opportunities that guide wildlife to existing bridges or create new structures in the Top 10 that provide a critical link to landscape connectivity for wildlife and ecological processes. Most of these important links in the landscape were protected in either state or federal ownership, or conservation easements. The landowners and protection status of these areas were also critical to channeling wildlife to either side of a highway.

The exact locations of the fences and other mitigation measures were digitized on ArcGIS maps that were then further developed and presented in this section to help readers view exactly where the recommended wildlife accommodations should be placed. Location information provided for surrounding features included mile post (MP) numbers, as well as bridge and culvert identification numbers, where applicable. The MP numbers are included within the Project Overview and Recommendations discussion sections for each of the Top 10, while bridge and culvert numbers are included in the Recommendations Summary tables at the end of the Recommendations section for each of the Top 10.

Once the mitigation opportunities were identified for each of the Top 10, the mitigation measures were used to estimate the percentage reduction in the wildlife crashes for each measure within each of the Top 10. The resulting percentages were used to develop a benefit-cost analysis of all the mitigation options for each of the Top 10 by dividing the estimated benefits of the reduced crashes by the estimated costs of the mitigation. The resulting ratio was provided for each of the Top 10, along with an estimate of the cost-recovery timeline for the mitigation recommendations.

6.1.1 Benefit-Cost Analysis

6.1.1.1 BENEFITS CALCULATIONS

There are several different methods to calculate the benefit-cost analysis when looking at solutions to reduce crashes. The first method is to use the FHWA's crash severity model, KABCO, to translate crash severity into societal cost for each crash type. The KABCO model classifies crashes into categories based on severity: fatal (K), major injury (A), minor injury (B), possible injury (C), and no apparent injury (property damage only [PDO]) (O). However, the FHWA national



costs are not always used by the states, and individual DOTs are permitted to use their own values for crashes. **Table 6-1** details the 2016 FHWA and MoDOT costs, adjusted for inflation.

Table 6-1: Crash Severity and Costs based on FHWA and MoDOT Costs

Crash Category	Type of Crash	FHWA Cost 2025 ¹	MoDOT Cost 2025 ²
K	Fatal	\$15,446,121	\$15,145,586
A	Serious Injury	\$895,694	\$878,265
B	Minor Injury	\$271,443	\$266,161
C	Possible Injury	\$185,429	\$168,412
O	No Apparent Injury	\$16,273	\$15,956
--	Minor Injury Average	--	\$204,700

¹ 2016 values (Harmon et al. 2018) adjusted for 2025 inflation using the U.S. CPI Inflation Calculator

(https://www.bls.gov/data/inflation_calculator.htm). Inflation from 2016 to 2025 was calculated at a rate of 0.36747.

² Taken from KABCO of Missouri Severity System (C. Knerr, personal communication, September 2025).

The second method to calculate the benefit-cost analysis of WVC reduction strategies is to also consider and monetize passive use costs (Donaldson et al. 2024), which are estimates of the value of an individual wild animal to the public. In 2019, for example, Colorado DOT monetized the value of a deer to Colorado society as \$2,061 (Kintsch et al. 2019). A similar estimate can be made for Missouri's valuation for an individual white-tailed deer. The 2025–2034 MDC Deer Management Plan (MDC 2025) estimates the economic contribution of the Missouri white-tailed deer herd at \$3.5 billion annually: \$1.5 billion in hunting related expenses, and \$2 billion in non-consumptive deer activities such as viewing with binoculars and other equipment, travel to see wildlife, etc. The total deer herd number in Missouri is estimated to be approximately 1.7 million individuals. Based on guidance from Jordan Meyer (MDC Policy Coordinator), when the number of Missouri white-tailed deer is divided into the \$3.5 billion valuation, the economic value of a single deer in Missouri can be estimated at \$2,058.

In October 2025, Mr. Meyer contacted MDC's Protection Branch Chief, Travis McLain, to ask what the value of a deer is when prosecuting poaching cases. Mr. McLain responded that the maximum fine for poaching a white-tailed deer in Missouri was \$2,000, with the possibility of penalties for antlered deer totaling an additional \$1,000 to \$5,000 per animal (RSMo Section 252.042). He concurred with Mr. Meyer's estimation that the value of \$2,000 per deer was correct. The benefits in this example include the reduction in WVC costs to society, and the reduction of value of killed deer due to the crash reductions. The 2019-2023 WVCs across all segments were 95 percent deer and 5 percent other, but for consistency the value of \$2,000 was applied to all crashes.

The annual cost of reported WVCs was calculated from the crash data and MoDOT crash severity monetary values for 2025. The recommended mitigation measures were expected to reduce crashes by a certain percentage. **Table 6-2** displays the levels of effectiveness of standard crash reduction measures based on several studies and the Colorado Benefit-Cost Analysis Worksheet (Kintsch et al. 2019; Kintsch et al. 2021).

Table 6-2: Estimated overall effectiveness of mitigation measures in reducing reported WVCs.

Mitigation Item	Average Effectiveness
Wildlife crossing structures and continuous fences over one mile of each corner of underpass and or overpass. This also includes escape ramps, and double cattle guards.	80 – 90% ¹
Add wildlife exclusion fence as a retrofit to existing structures that can allow deer and other larger wildlife to pass beneath the road. This also includes escape ramps, and double cattle guards.	83% ¹
Short lengths of fence less than 1 mile in conjunction with crossing structures or existing bridges and culvert that allow deer to pass beneath the road.	53% ²

¹ Kintsch et al. 2019; Sawyer et al. 2012; Clevenger & Barrueto 2014; Huijser et al. 2009.; ² Huijser et al 2016.

The length of time the mitigation is expected to exist on the landscape is also estimated (**Table 6-3**).

Table 6-3: Mitigation items expected service life.

Mitigation Item	Expected Service Life	Reference
Bridge, Culvert, Arch Underpass or Overpass	75 years	Bridge and culvert infrastructure are typically estimated to last 75 years. A Utah bridge wildlife overpass was placed in 1975 over IS-15 and is still in service. Missouri's system of roads has culverts and bridges that were built in the 1930's and were still serving in 2025, as their replacement projects are planned (C. Knerr, MoDOT, personal communication, 2025).
Wildlife Exclusion Fence 8 feet high	50+ years	V-mesh fence placed to exclude deer out of neighborhoods in the 1980's is still in service in Utah's Cache Valley. Fifty years is a minimum and is used as an across-the-board number of years.
Escape Ramps	30+ years	Utah US 91 in the Wellsville Mountains – escape ramps were placed in 1995 and are still effective. They do need soil enrichment as they slump over decades of time.
Double Cattle Guards	25 – 50 years	Many older cattle guards at interstate interchanges that were placed in the 1960's and 1970's across the U.S. are still in service.

The value of the wildlife saved from WVC mortalities is calculated from an individual animal's worth and multiplied by the annual average number of reported WVCs from the previous five years of crash data to get a value of wildlife killed annually, in the same manner Colorado DOT estimated the deer values for crashes prevented (Kintsch et al. 2019).



These values are combined to estimate the value of the mitigation over its expected service life. The final monetary value of these benefits (**Table 6-4**) is inserted into the numerator of the benefit-cost equation (**Section 6.1.1.3**).

Table 6-4: Example of MoDOT crash costs over time, averaged for annual costs of crashes for a segment.

Type Of Crash	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
Total PDO crashes	15	\$15,956	\$239,340	--
Total Minor Injury	1	\$204,700	\$204,700	--
Total Serious/Disabling Injury	0	\$787,600	0	--
Total Cost for 5 Years	--	--	--	\$444,040
Average Crash Cost Per Year	--	--	--	\$88,808

6.1.1.2 MITIGATION COST CALCULATIONS

The denominator in the benefit-cost equation is the cost of the mitigation plus its maintenance over time. This includes the cost of the wildlife crossing structures, fence, escape ramps, gates, and double cattle guards, plus an annual maintenance cost multiplied by the years the mitigation is expected to last. The costs for infrastructure had standard values that were adjusted for each prescribed mitigation. The costs were derived from current HDR estimates for fences, updates to the Colorado costs in their benefit-cost worksheets to price with inflation since 2019 (Kintsch et al. 2019), and estimates from T. Miller at Contech Solutions, a company that has helped design and build dozens of wildlife underpasses and overpasses. **Table 6-5** below illustrates generalized costs of wildlife mitigation components.

Table 6-5: 2025 Estimated Costs of Mitigation Items.

Item	Cost	Notes
Fence per linear foot = on one side of the road.	\$30	HDR estimates, considered high by MoDOT Project Development Staff and based on past MoDOT projects, which were \$15.87/per foot per side (C. Knerr, MoDOT personal communication).
Estimated Fence Swing Gate – 16 feet	\$1,500	P. Cramer estimate increase from Colorado DOT form of \$1,200 using CPI inflation calculator estimate of a 26% increase in cost and rounding to nearest 100.
Estimated cost per 3:1 Escape Ramp	\$22,000	P. Cramer estimate increase from Colorado DOT form using CPI Inflation Calculator. Considered a high by MoDOT Project Development Staff, who estimated the cost to be about \$18,636.
Cost per Double Cattle Guard – Driveways Round bars – 16 feet wide	\$35,000	P. Cramer estimate increase from CDOT form using CPI Inflation Calculator and reduced because MoDOT had estimates in Fall of 2025



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Item	Cost	Notes
		of \$30,000, so the initial \$50,429 was too high.
Cost per Double Cattle Guard – Two lane roads Round bars –32 feet wide	\$78,000	P. Cramer estimate increase from CDOT form using CPI Inflation Calculator
Bridge or Large Arch Underpass	@283/ft ²	P. Cramer estimate increase from CDOT form using CPI Inflation Calculator. Includes turn key installation. A 42' W x 64' L structure would cost \$604,800. Increase cost by ~3% /year
Contech Engineered Solutions Arch Underpass beneath 2 lanes, sized for wildlife crossing structure	\$421,500 (structure), \$599,875 (with installation)	Based on October 2025 preliminary estimates from Contech Engineered Solutions
Bridge or Arch Overpass under 4 lanes with divided median	\$283/ft ² This equals \$1,440,000	P. Cramer estimate increase from CDOT form using CPI Inflation Calculator. Includes turn key installation. A 100'W x 64' L structure would cost \$1,440,000. Increase cost estimate by ~3% per year.
Maintenance of only wildlife exclusion fence plus escape ramps and cattle guards	\$1,000/year	P. Cramer rough estimate used in past DOT calculations (Cramer et al. 2022a)
Maintenance of wildlife crossing structures, fence, escape ramps, and cattle guards	\$1,000/year	P. Cramer rough estimate used in past DOT calculations (Cramer et al. 2022a)

The number of linear feet of fence, plus the number of each mitigation item are calculated for the mitigation measures prescribed for each segment. These values are entered into a pre-programmed Excel spreadsheet of costs to calculate the total cost of prescribed mitigation measures. This includes the annual maintenance cost times the number of years the service life of the mitigation.

Table 6-6: Example calculations for estimating costs of proposed mitigation infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	35,764	\$30 per linear foot	\$1,072,920
Gates	17	\$1,500	\$25,500
Escape Ramps	22	\$22,000	\$484,000
Driveway Double Cattle Guards 16 foot	0	\$35,000	\$0
Road Double Cattle Guards 32 foot	0	\$78,000	\$0
Materials Total	--	--	\$1,582,420
Maintenance	50 years	\$1,000 per year	50,000
Grand Total	--	--	\$1,632,420



6.1.1.3 THE BENEFIT-COST EQUATION

The calculations to determine benefits of specific mitigation measures can be approached in several ways. A threshold value can be calculated where the economic benefits equal the costs. This equates to a benefit-cost ratio of 1:1. If the benefit-cost ratio is greater than 1:1, the project is expected to deliver a positive value (Donaldson et al. 2024). A minimum number of years can then be calculated to predict when the mitigation measures deliver enough reduced WVCs that the benefits are equal to or greater than the cost. Another approach can be to look at what the needed cost of a mitigation strategy would need to allow the mitigation to break even with the crash reduction and costs, i.e. at what value of mitigation measure would the benefits outweigh the costs. This Study utilized the first approach, as most of the Top 10 benefit-cost ratios were above one.

The benefit-cost calculations for this Study used the following factors:

Benefits

- Annual Average Wildlife Crash Costs – The number of fatal, injury, and PDO crashes with wildlife in the project area over the past 5 years multiplied by the crash severity value of each crash type, summed and divided by 5 to get an annual crash cost per year:

$$\bigcirc \frac{[\text{Number of fatal, injury, and no injury WVCs over the past 5 years}] \times [\text{Crash severity value of each crash type}]}{5}$$

- Annual Wildlife Value – The value of deer (\$2,000), multiplied by the annual average number of reported crashes with wildlife in the segment:

$$\bigcirc ([\text{Value of deer } (\$2,000)]) \times [\text{Annual Average number of reported WVCs in the segment}]$$

Value of annual crashes and wildlife killed = Crash Costs + Wildlife Value

- Percentage Reduction – Estimate the percentage reduction in crashes by dividing the number of reported crashes that were within the future potential mitigation location, which was the area to be fenced in the recommendation, by the total crashes in the specific Top 10 location and reduce (multiply by) the percentage of expected numbers of reduced crashes in the future by the expected crash decrease from the proposed mitigation method. For example, if the recommended fences are where 11 out of 14 past crashes occurred in the segment, divide 11 by 14 to get approximately 78 percent of the crashes in that area. Then reduce that percentage by an expected percentage decrease from fences. For this example, it would be expected that the fences would reduce the 14 crashes by about 60 percent.
- Years in Service – Estimated service life of the recommended mitigation in years. For all Top 10 recommendations in these analyses, the service life was 50 years.

Benefits

$$= [\text{Annual Value of Crashes and Wildlife Killed}] \times [\text{Percent Expected Reduction}] \times [\text{Years in Service}]$$

Costs

- Mitigation Infrastructure – The cost of all structures, fences, gates, escape ramps, and double cattle guards.
- Total Maintenance Costs – Estimated annual costs of maintenance multiplied by the service life of the infrastructure in years. For all the Top 10, this equated to \$1,000 per year x 50 years = \$50,000
 - $[Estimated\ annual\ costs] \times [Service\ life\ in\ years]$

$$Costs = [Mitigation\ Infrastructure] + [Total\ Maintenance\ Costs]$$

$$Final\ Equation = \frac{Benefits}{Costs}$$

The methods described in this section were applied to each of the Top 10 in a synthesis of data gathered earlier in this study to first identify mitigation recommendations along with their estimated costs and predicted reductions in future crashes. Secondly, the benefit-cost analysis approach presented above was applied to each of the Top 10's mitigation measures to help evaluate if the recommended actions would pay for themselves over the service lifetime of the mitigation infrastructure. The data and maps developed can assist MoDOT and partners in pursuing various funding sources, both transportation and wildlife related. The resulting information will help provide the necessary data to help inform MoDOT in the transportation planning process in order to consider wildlife in both upcoming transportation projects and stand-alone wildlife crossing projects.

6.2 Pershing State Park

6.2.1 Project Overview

The Pershing State Park area is an exemplary Top 10 to reduce WVCs and provide connectivity for wildlife in the area. With the land protection status of the state park on both sides of U.S. 36 (US 36) in its central area, a private land conservation easement, natural riparian forests that are connected north and south to other areas in the landscape, and existing bridges and culverts, it is a location where wildlife mitigation can be added with small lengths of wildlife exclusion fence attached to existing bridges that wildlife are already using. In the feasibility analysis of the Top 10, the Pershing State Park area ranked number one, for the protected lands, existing infrastructure that could be retrofitted with fences, and potential to include wildlife mitigation into an upcoming MoDOT STIP project on a bridge. Over this 12-mile project area, there were 44 reported wildlife crashes from 2019 to 2023. This equated to 0.73 wildlife crashes per mile per year. Six of the past wildlife crashes resulted in minor injuries to motorists.



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Table 6-7: Pershing State Park Description and Criteria

Name: Pershing State Park	
MoDOT District: Northwest	
County: Linn	
Road and Mile Posts: US 36 MP 83 – 95	
Total Miles: 12	
STIP Description: Pavement repair from west of Missouri Route 13 to 2 miles east of Route 129 near Bucklin. Pavement resurfacing in Carroll, Chariton, Linn, and Randolph Counties, including Routes T, E, UU, EE, W, TT, and ZZ. Potential pavement resurfacing on Route NN in Carroll County and Routes C and UU in Chariton County. Pavement preservation treatment in Daviess, Grundy, and Linn Counties, including Routes 36, 69, and 6. Bridge improvements in Linn County over Big Turkey Creek and Big Turkey Creek Overflow 1 mile east of Laclede, including bridges A0793 and A0845.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	44
Wildlife Crashes per Mile per Year	0.73
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	27%
<i>Ecological</i>	
AADT	10,897
Occupied Habitat	Up to 4 priority species known to occur.
Predicted Suitable Habitat	Up to 17 priority species including: black-tailed jack rabbit, eastern tiger salamander, American badger, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle
MDC CCS Management Tiers	Locust Creek Stream Reach COA – Tier 2 Lower Grand River Landscape COA – Tier 2 Locust/Yellow Creek Priority Watershed – Tier 3
Named Streams	Turkey Creek, Parson Creek, Muddy Creek, Locust Creek, Little Turkey Creek, Hickory Branch
Bridges and Culverts	14 bridges and 4 box culverts
<i>Feasibility</i>	
Land Use	25% Developed
Protected Areas	Locust Creek Covered Bridge State Historic Site Pershing State Park Cordgrass Bottoms Natural Area Wetland Reserve Program Easements
<i>Qualitative Review</i>	
Constructability	3
Land Use	3
STIP Rating	3

Figure 6-1: Pershing State Park Overview Map, West.

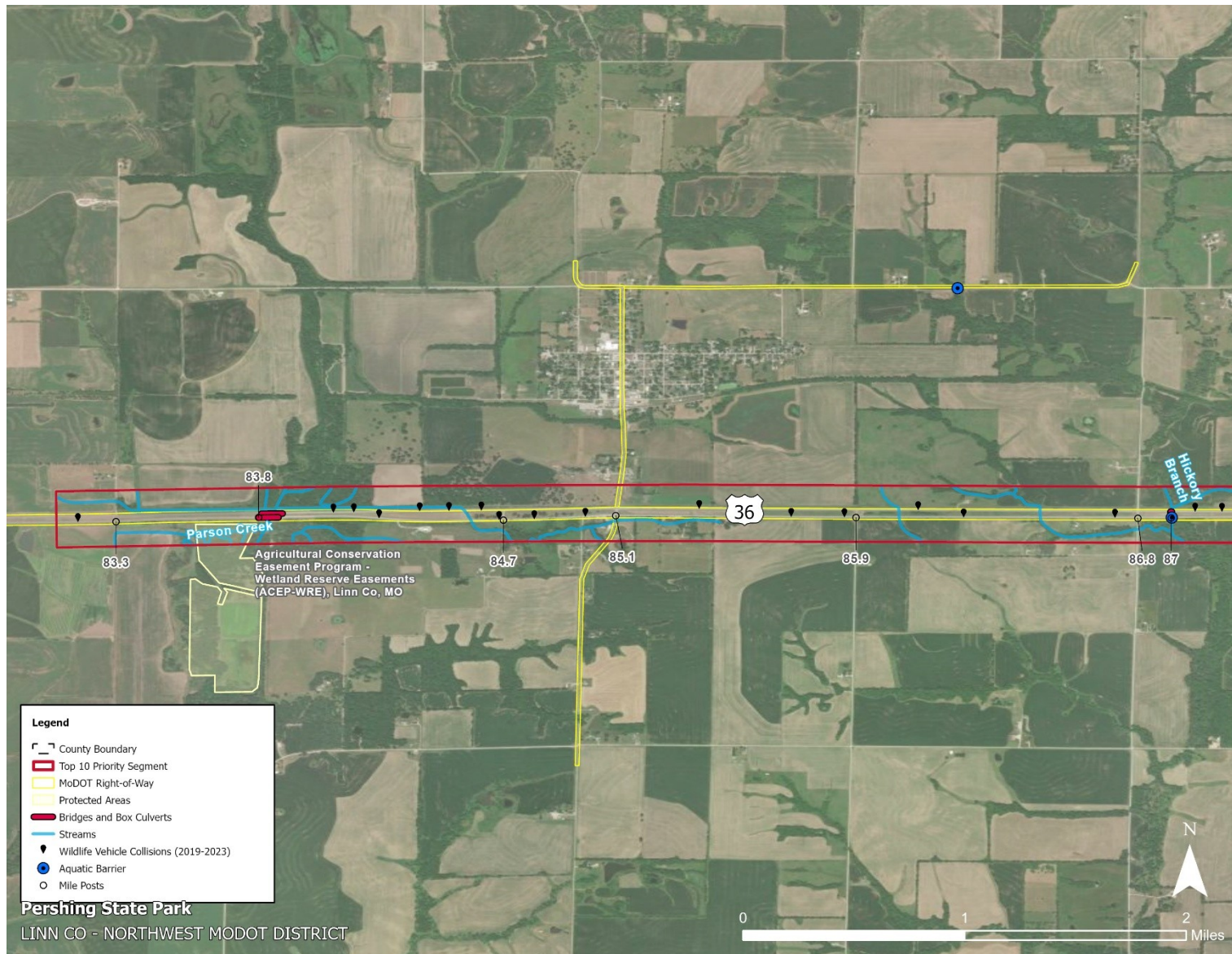


Figure 6-2: Pershing State Park Overview Map, Center.

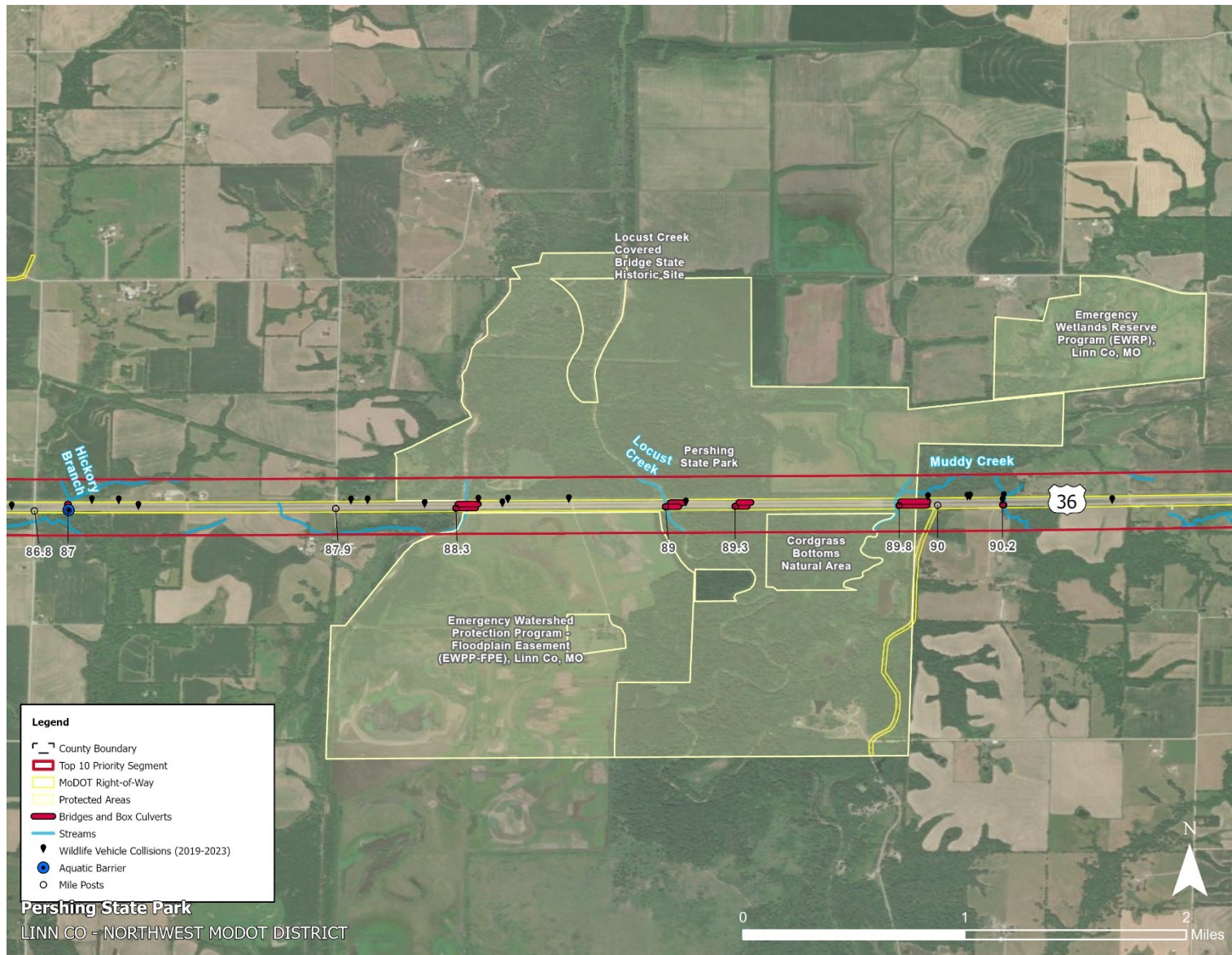
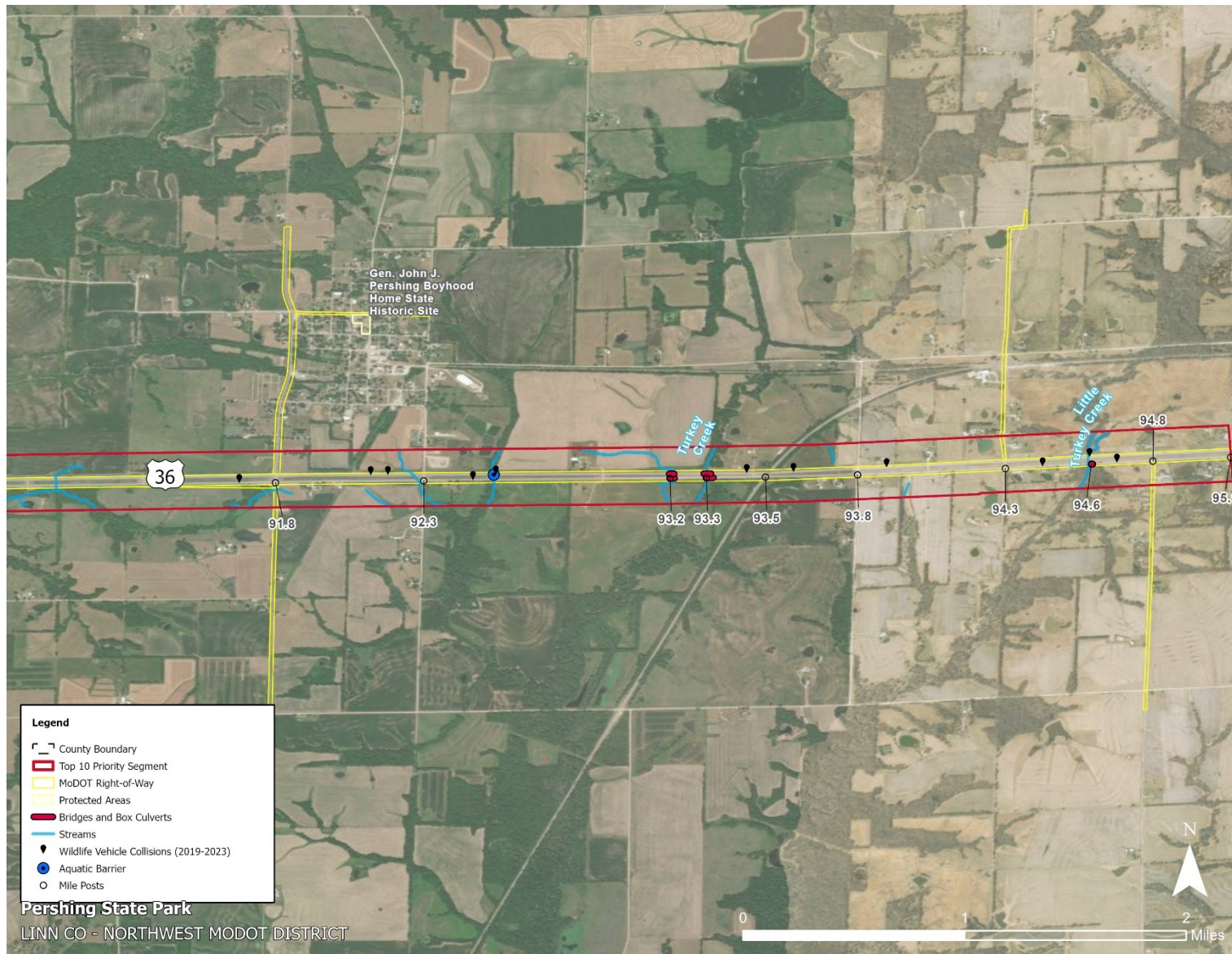


Figure 6-3: Pershing State Park Overview Map, East.





6.2.2 Recommendations

This site is a prime area for wildlife movement and to add fences to existing bridges and culverts to encourage wildlife to use existing infrastructure. The most important riparian forests are protected either within Pershing State Park, or nearby areas protected in conservation easements. There is landscape connectivity north and south of Pershing State Park in the riparian forests, making protecting wildlife connectivity here an important ecological goal. The multiple existing long, multi-span bridges are perfect for wildlife movement and had signs of high white-tailed deer usage during the field investigation.

U.S. 36 along this Top 10 segment has three existing culverts and six pairs of bridges to accommodate waterbodies. The recommended mitigation measures to reduce WVCs and promote connectivity are simply to clean out an existing culvert and place wildlife fences. The total length of the wildlife fences throughout this 12-mile site would be 29,125 feet, which equals 2.76 miles of road where there is fence on both sides. The longest recommended fence stretch is 8,260 feet (1.56 miles) between Higgins Ditch to the west and the Locust Creek Overflow to the east. The remainder of the fences are “wing” fences that would guide wildlife to existing bridges and a culvert. These fences would be several hundred to approximately 1,000 feet long. The mitigation recommendations include 23 maintenance gates at the existing bridges, 14 escape ramps, and four driveway cattle guards. The location of the 14 escape ramps should be decided with MDC and MoDNR staff. There is an upcoming project on the Turkey Creek bridges and the Turkey Creek Overflow bridges. The fences could be installed during this project.

American black bears were a consideration in these recommendations, as Missouri’s black bear population is expanding into this area. In 2025, a black bear was involved in a vehicle collision around the Sheridan River to the east near New Cambria. Black bears that are new to an area disperse without knowledge of the locations of where the existing bridges are located to pass beneath the highway. The recommended fences are for the wildlife that exist now in the Pershing State Park area, and for those dispersing in from other areas like the black bear.

MoDNR owns and operates the State Park. They will need to be contacted as soon as there is any consideration for these mitigation measures.

The estimated construction costs for the recommended mitigation would be approximately \$1.4 million. The benefits were calculated over 50 years, for a 50 percent reduction in wildlife crashes, with the value of reduced crashes estimated from MoDOT 2025 crash cost estimates. The benefits value over those 50 years was estimated at \$9.6 million. The benefit-cost ratio equaled 6.84. This value is very high, making the costs of mitigation able to pay for itself in reduced crash costs and white-tailed deer not killed in less than eight years.

6.2.2.1 HICKORY CREEK BRANCH CULVERTS – MP 87

Short Term Actions

Clean out vegetation at entrance and inside western cell of double box culvert.

Figure 6-4: Hickory Creek Branch Box Culvert Outlet at MP 87.



Retrofit Infrastructure

This would include placement of fences and creation of wildlife-human pathways beneath bridges along waterways.

- Total Fence – 4,259 feet
 - Southwest Corner Fence – 576 feet, extend to Crow Drive
 - Northwest Corner Fence – 558 feet, extend to Crow Drive
 - Northeast Corner Fence – 1,477 feet, extend to the Bowyer Trust land
 - Southeast Corner Fence – 1,472 feet, extend to across from Bowyer Trust land
 - West Median Fence – 89 feet
 - East Median Fence – 87 feet
- Escape Ramps – Two, place them on north and south side of highway, east of the bridge, where the forest ends and cleared fields begin on south side.
- Gates – Four (for bridge access). Two on north, two on south.

6.2.2.2 PARSON'S CREEK BRIDGES – MP 83.82

An Agricultural Conservation Easement Program Wetland Reserve Easement is located on the south side of the highway, on the west side of Parson's Creek. This should remain undeveloped. The property to the east has a fair amount of forested lands south of the highway. Lands to the north have many forested wetlands. The only land that is cleared and not in a natural state is the land northwest of the bridge.

Figure 6-5: Parson's Creek Bridges at MP 83.82



Retrofit Infrastructure

The north bridge needs new decking or repair. There is no deficiency in bridge inventory, however, it was noted that there is bank slump with minimal damage. Fencing should be placed off fence abutments when scheduled bridge repairs occur.

- Total Fence – 14,681 feet
 - Southwest Corner Fence – 5,394 feet
 - Northwest Corner Fence – 5,364 feet
 - Northeast Corner Fence – 1,926 feet
 - Southeast Corner Fence – 1,956 feet, extend east to residential driveway
 - West Median – 41 feet
- Escape Ramps – Four minimum, two on north, two on south. Place escape ramps in coordination with MoDNR and any nearby natural resource agency landowners.
- Gates – Two.
- Double Cattle Guards – Two, one for the north side driveway northwest fence; one for south side driveway southwest fence.

Figure 6-6: Median between the Parson's Creek Bridges.



6.2.2.3 UNNAMED BOX CULVERT– MP 92.5

Short Term Actions

Maintain vegetation control near entrances so wildlife can find the culvert.

Figure 6-7: Unnamed Box Culvert at MP 92.5.



6.2.2.4 HIGGINS DITCH BRIDGES – MP 88.3

The multi-span bridges at this site are perfect for wildlife movement. Many signs of white-tailed deer use were noted in areas under the bridges. The Locust Creek Covered Bridge State Historic Site encompasses the land on the north side of the highway. The land to the southeast of the ditch and south is an Emergency Watershed Protection Program Floodplain Easement.

Figure 6-8: Higgins Ditch Bridges at MP 88.3.



Retrofit Infrastructure

- Total Fence – 11,061 feet
 - Southwest Fence – 2,142 feet, extend to Danube Drive
 - Northwest Fence – 2,118 feet, extend to Danube Drive
 - West Median Fence - 37 feet
 - East Median Fence – 40 feet
 - Northeast Fence – 3,352 feet, extend to Locust Creek (Higgins Ditch – Locust Creek Fence Line North)
 - Southeast Fence – 3,372 feet, extend to Locust Creek (Higgins St – Locust Creek Fence Line South)
- Double Cattle Guards – One, driveway width placed 1,800 feet east of the bridge at a long driveway to the south.
- Escape Ramps – Four, on the Higgins Ditch – Locust Creek Fence Line. Two ramps on north side, two ramps on south side.
- Gates – Four, one on south and one on north side of highway, east of the Higgins Ditch for MoDOT access; one on north and one on south side of highway west of the Higgins Ditch.

6.2.2.5 LOCUST CREEK BRIDGES – MP 89

These multi-span bridges are perfect for wildlife movement and there were many white-tailed deer tracks at the time of the field investigation.

Figure 6-9: Locust Creek Bridges at MP 89.



Short Term Actions

Vegetation in bridge area should be mowed, especially in areas near bridge approaches in early summer, so wildlife can find the bridges. There is the greatest amount of landscape connectivity between this Locust Creek bridge and the Locust Creek Overflow bridge. These two bridge areas are the most important places in the entire area to protect and guide wildlife to them. There are fewer crashes here because wildlife are using the bridges. However, placing fence between them to guide wildlife will help individuals that are new to the area, such as dispersing black bear.

- Total Fence – 1,088 feet.
 - Southwest – See above for the North Higgins Ditch – Locust Creek Fence Line details.
 - Northwest – See above for the North Higgins Ditch – Locust Creek Fence Line details.
 - Northeast – See Locust Overflow Fence Line North, discussed below.
 - Southeast – 1,015 feet, Locust Creek – Locust Overflow Fence Line South.
 - West Median Fence – 37 feet.
 - East Median Fence– 36 feet.
- Escape Ramps – Two, one on each side of the highway.
- Gates – Five, one to each of the four corners, and on southwest fence to allow for a secondary gate where there is a path to the west.

6.2.2.6 LOCUST CREEK OVERFLOW BRIDGES – MP 89.3

Another set of long, high bridge spans, perfect for wildlife movement. There were signs white-tailed deer are using the bridges.

Figure 6-10: Deer tracks below the Locust Creek overflow bridges at MP 89.3.



Retrofit Infrastructure

- Total Fence – 3,337 feet.
 - Northwest Fence – 1,013 feet (Locust Creek – Locust Overflow North Fence Line)
 - Northeast Fence – 1,110 feet, extend east to just past the end of the forest on the north side.
 - Southeast Fence – 1,139 feet extend east to match the north fence. These fences are not extended to Muddy Creek because there were no reported crashes with wildlife in this stretch.
 - West Median Fence – 40 feet.
 - East Median Fence – 35 feet.
- Escape Ramps - Two
- Gates - Four, added to all four corners of bridge.

6.2.2.7 MUDDY CREEK BRIDGES – MP 89.8

These long multi-span bridges are perfect for wildlife movement. The span of the bridges is over 500 feet and is used by wildlife, as noted during the field investigation.

Figure 6-11: Muddy Creek Bridges at MP 89.8.



Retrofit Infrastructure

Place wildlife exclusion fence from the east abutments of the bridge on both sides of the highway and extend eastward 312 feet to an existing small culvert; end before Highway 130.

- Total Fence – 854 feet.
 - Northeast Fence – 409 feet.
 - Southeast Fence – 404 feet
 - East Median Fence – 41 feet.

6.2.2.8 TURKEY CREEK BRIDGES – MP 93.2, 93.3, AND 94.6

This is the final structure on the east of the Pershing State Park segment where there is recommended wildlife mitigation. There was just one reported crash with wildlife in the area recommended for wing fences off the Turkey Creek bridges. The land is all privately owned around the creek, and most is in agricultural production. These facts make this the least important area for mitigation for wildlife crashes in this Top 10 segment. However, this is the location of an upcoming MoDOT project; therefore, adding fences would potentially be feasible.

Figure 6-12: Animal use path below the Turkey Creek Bridges at MP 93.3.



Retrofit Infrastructure

- Total Fence – 3,245 feet.
 - Southeast Fence – 524 feet to the Turkey Creek Overflow bridge
 - Northeast Fence – 537 feet to the Turkey Creek Overflow bridge
 - Northeast Fence – 1,096 feet of fence to the rail line
 - Southeast Fence – 927 feet of fence to the rail line
 - Total Median Fences – 163 feet
 - 58 feet for Turkey Creek Overflow Median East
 - Two fences, 103 feet between the Turkey Creek bridges
- Escape Ramps – Two, one on the north side, one on the south side.
- Gates – Four
- Cattle Guards – One, located in the driveway to the north.

6.2.2.9 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in Table 6-8 and depicted in **Figure 6-13**, **Figure 6-14**, and **Figure 6-15**.

Table 6-8: Pershing State Park Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Hickory Branch Creek Culverts – A4372 & A1168 	87	Cut back vegetation at entrances – especially west box culvert to allow view through.	Place fence to Crow drive on west, and to lands on east. Make sure to fence the median. Add gates on fences near structure.	None
Parson's Creek Bridges – A1167 & A3253 	83.82	None	Place fence lines off of each corner of the bridge abutment. East fences extend about 1,930 feet to end of east side forests, and before the south side driveway. West fence extends about 5,370 feet to the residential driveway on the south side. Add gates on fences near structure to allow for maintenance equipment.	North bridge needs repair or decking – make adjustments during that project.
Unnamed Box Culvert	92.5	Maintain vegetation control at entrance	None	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
				
Higgins Ditch Bridges – A1169 & A3254 	88.3	None	Install wing fences approximately 2,100 feet to the west to Danube Drive and approximately 3,350 feet east to Locust Creek Place. Add gates on fences near structure.	None
Locust Creek Bridges – A1170 & A3255 	89	None	Install wing fence to Higgins Ditch to the west, and to Locust Overflow bridge to the east and southeast. Add gates on fences near structure.	None
Locust Creek Overflow Bridges – A 3256 & A1171	89.3	None	Fence to the west to Locust Creek extending	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
			1,013 feet. Fence to the east extending approximately 1,110 feet. Add gates on fences near structure.	
Muddy Creek Bridges – A1172 & A3257 	89.8	None	Place 400 feet of fence eastward from the north and south bridges on the east side. Place to existing culvert.	None
Turkey Creek Bridges – A4639 & A0835 (93.2); A4640 & A0793 (93.3); A0794 (94.6) 	93.2, 93.3, 94.6	None	STIP has this bridge and the overflow bridge listed for improvements. Add fence at this time: 530 feet to the west to Turkey Creek overflow bridge, and 1,000 feet to east to rail line.	None

Figure 6-13: Pershing State Park Mitigation Recommendations, west.

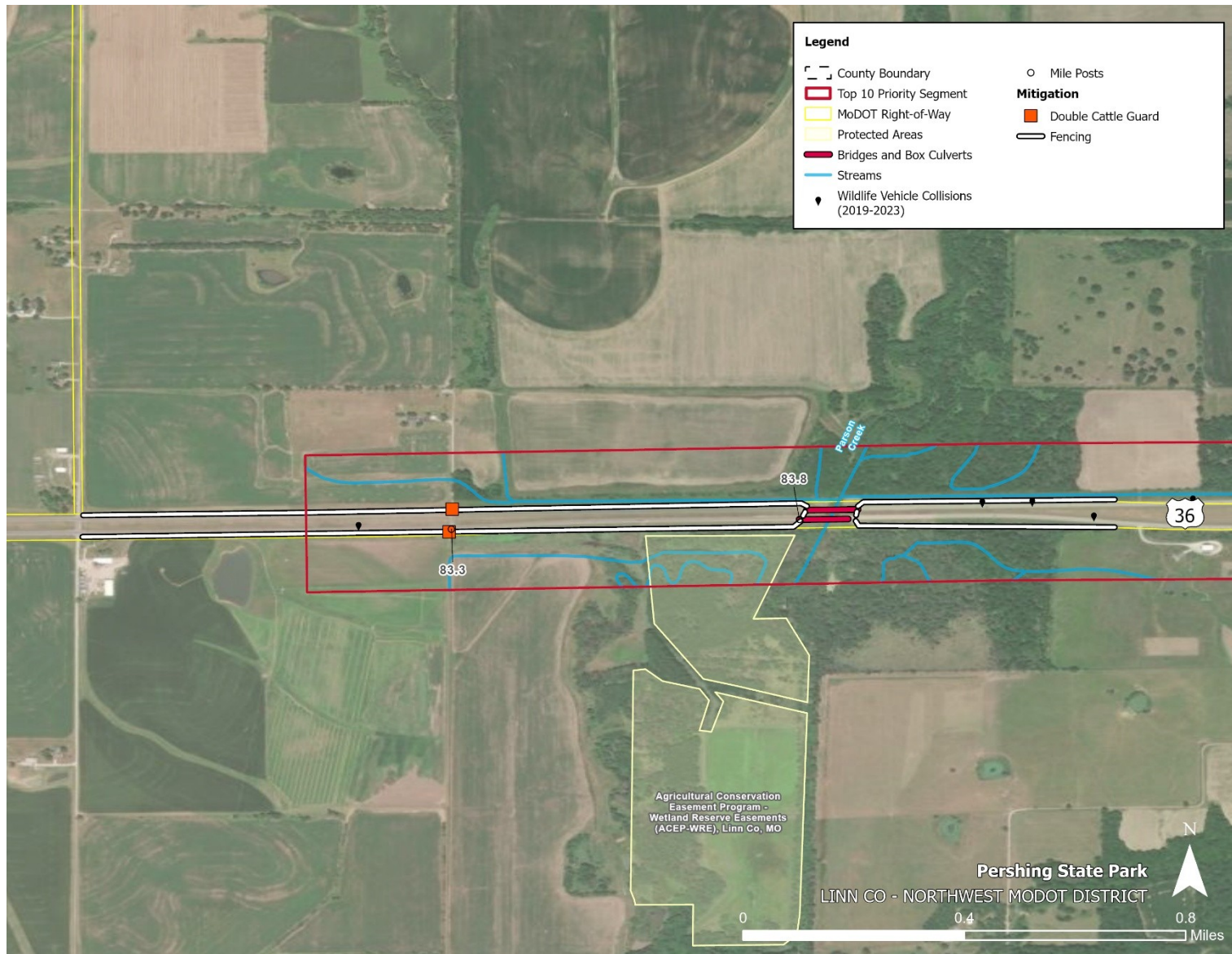


Figure 6-14: Pershing State Park Mitigation Recommendations, East of Center.

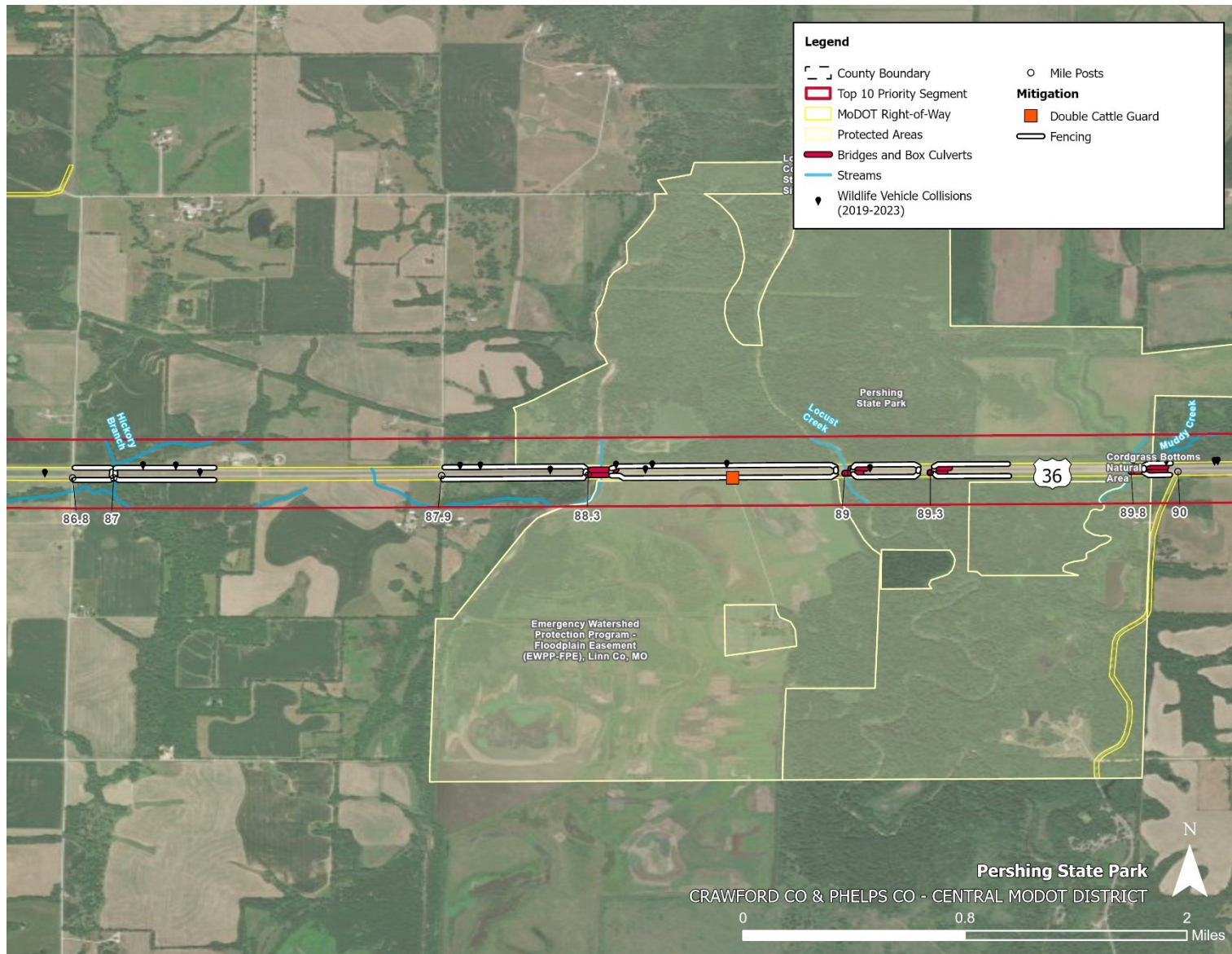
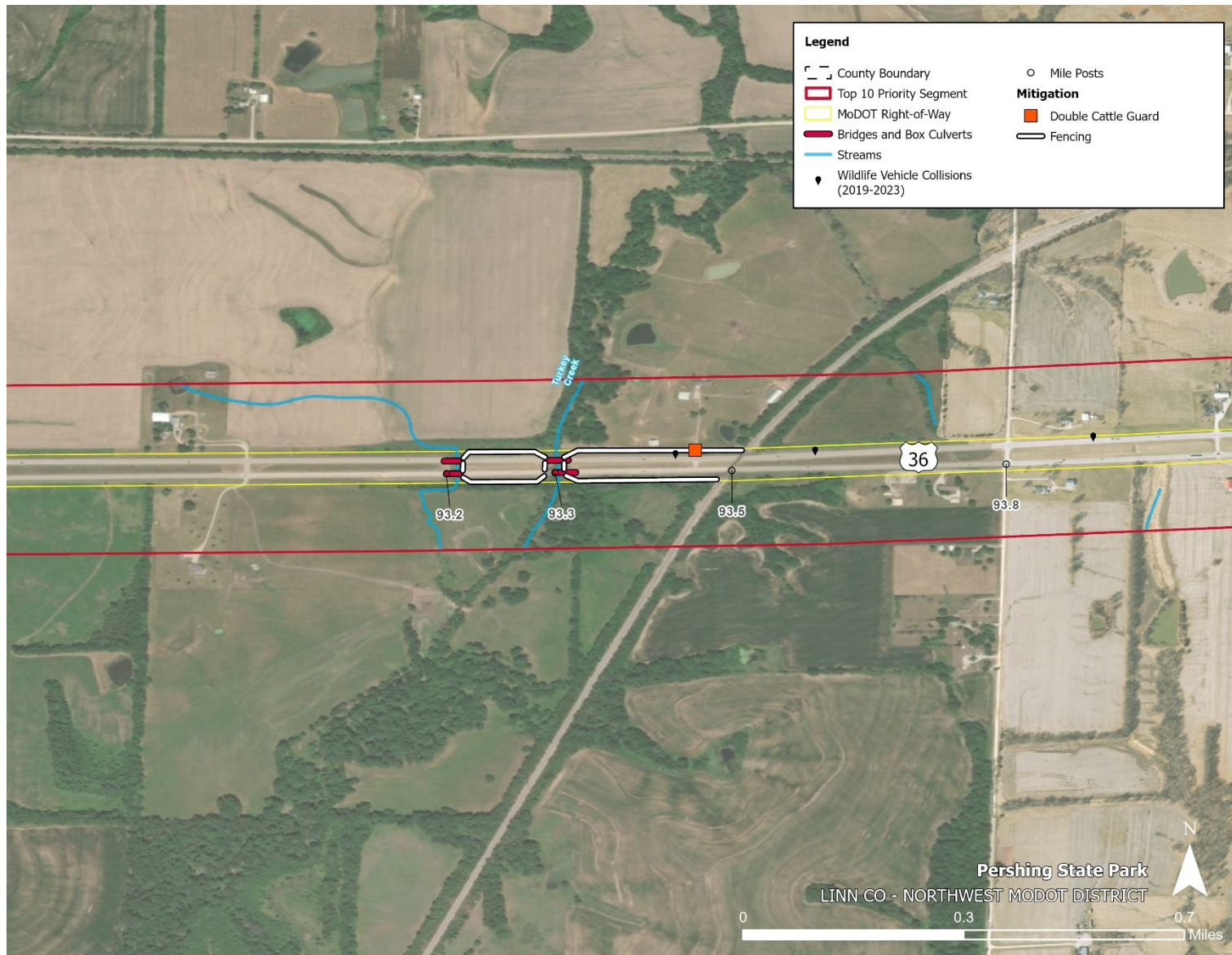


Figure 6-15: Pershing State Park Mitigation Recommendations, Center.





6.2.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 7.73, with a payback period of 6.47 years.

Table 6-9: Pershing State Park Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	38,525	\$30 per linear foot	\$1,155,750
Gates	23	\$1,500	\$34,500
Escape Ramps	16	\$22,000	\$352,000
Driveway Double Cattle Guards 16 foot	4	\$35,000	\$140,000
Materials Total	--	--	\$1,682,250
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$1,732,250

Table 6-10: Pershing State Park WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	38	\$15,956	\$606,328	--
Minor Injury	6	\$204,700	\$1,228,200	--
Serious / Disabling Injury	0	\$787,600	0	--
Cost For 5 Years	--	--	--	\$1,834,528
Average Cost Per Year	--	--	--	\$366,906

Table 6-11: Pershing State Park Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>			
Benefits Values	$(366,906 + (2,000 \times 8.8)) \times 0.7 \times 50$			
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>			
Costs Values	$1,682,250 + (1,000 \times 50)$			
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit	
\$13,457,696	\$1,732,250	7.77	6.44 years	



6.3 Four Rivers Conservation Area

6.3.1 Project Overview

Interstate 49 (IS-49), north of the small community of Nevada in western Missouri, crosses numerous natural drainage features with multi-span bridges. The mix of large bridges over those waterways, and Conservation Areas with protected forests on either side of IS-49 helped these areas rise to the level of a Top 10. For this analysis, the Four Rivers Conservation Area was divided into two IS-49 highway portions, referred to as the Douglas Branch Conservation Area, between milepost (MP) 107-110 (the southern portion), and the Horton Bottoms Natural Area, between MP 112.8 and 114.3 (the northern portion).



Missouri Statewide Wildlife Vehicle Collision Study Alternatives Analysis and Recommended Improvements

Table 6-12: Four Rivers Conservation Area Description and Criteria.

Name: Four Rivers Conservation Area	
MoDOT District: Southwest	
County: Vernon	
Road and Mile Posts: Interstate 49, MP 107 – 110 and 112 – 114	
Total Miles: 5	
STIP Description: Bridge rehabilitation on southbound lanes over the Little Osage River, Little Osage River Overflow and Douglas Branch. Project involves bridges A2629, A2614, A2630 and A2631. Funds scheduled for 2026.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	16
Wildlife Crashes per Mile per Year	0.46
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	23%
<i>Ecological</i>	
AADT	11,032 – 11,275
Occupied Habitat	Up to 2 priority species known to occur.
Predicted Suitable Habitat	Up to 18 priority species including: Kirtland's snake, black-tailed jackrabbit, eastern tiger salamander, American badger, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, and alligator snapping turtle.
MDC CCS Management Tiers	Horton Bottoms Natural Area – Tier 1, Four Rivers Wetland and Wet Prairie Complex Landscape COA – Tier 2, and Douglas Branch – Tier 4.
Named Streams	Little Osage River, Marmaton River, Douglas Branch
Bridges and Culverts	11 bridges
<i>Feasibility</i>	
Land Use	26 – 27% Developed
Protected Areas	August A Busch Jr. Memorial Wetlands at Four Rivers Conservation Area, Horton Bottoms Natural Area, Douglas Branch Conservation Area, Wetlands Reserve Program.
<i>Qualitative Review</i>	
Constructability	3
Land Use	2.67 – 3
STIP Rating	2

Figure 6-16: Four Rivers Conservation Area Overview Map, Douglas Branch.

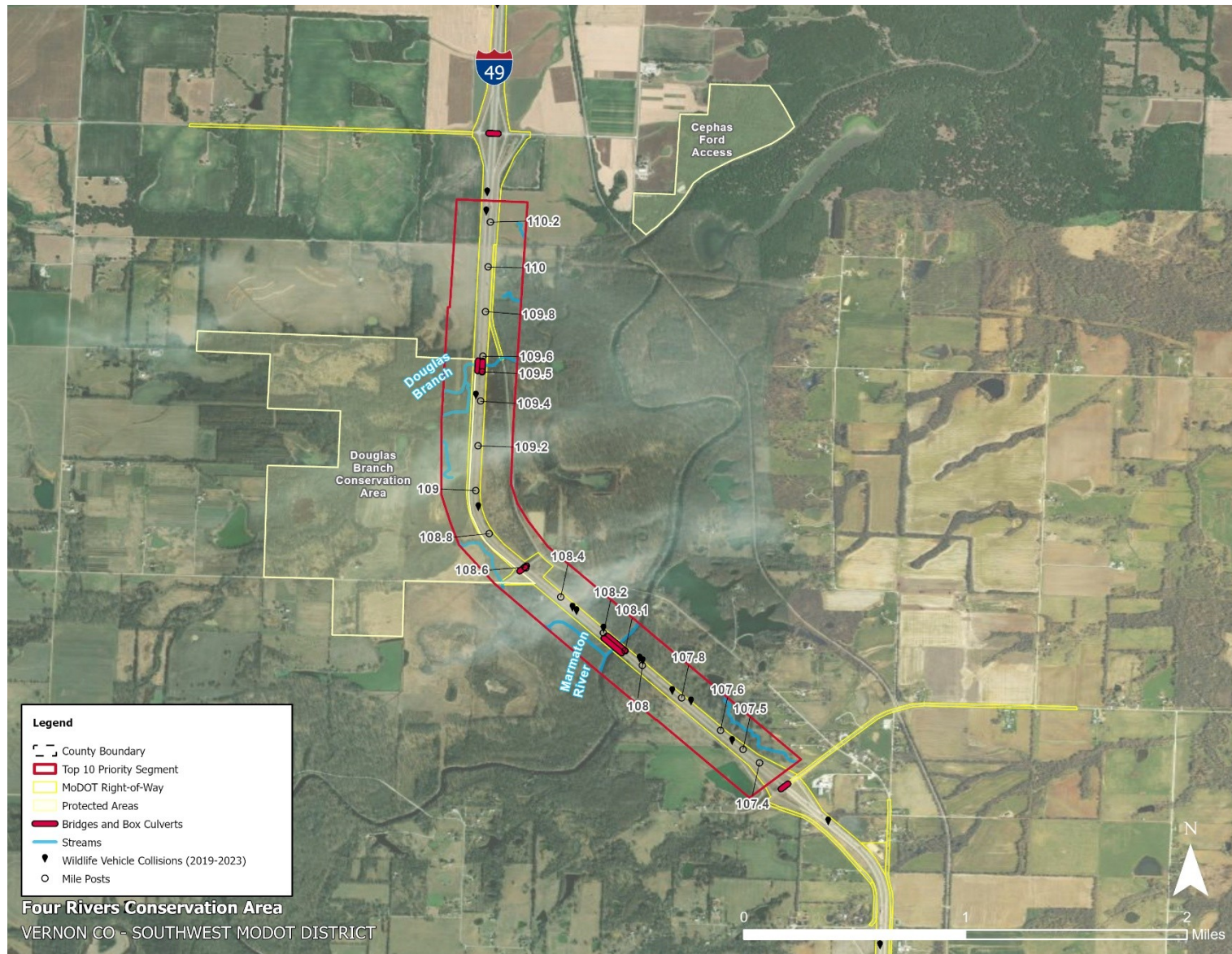
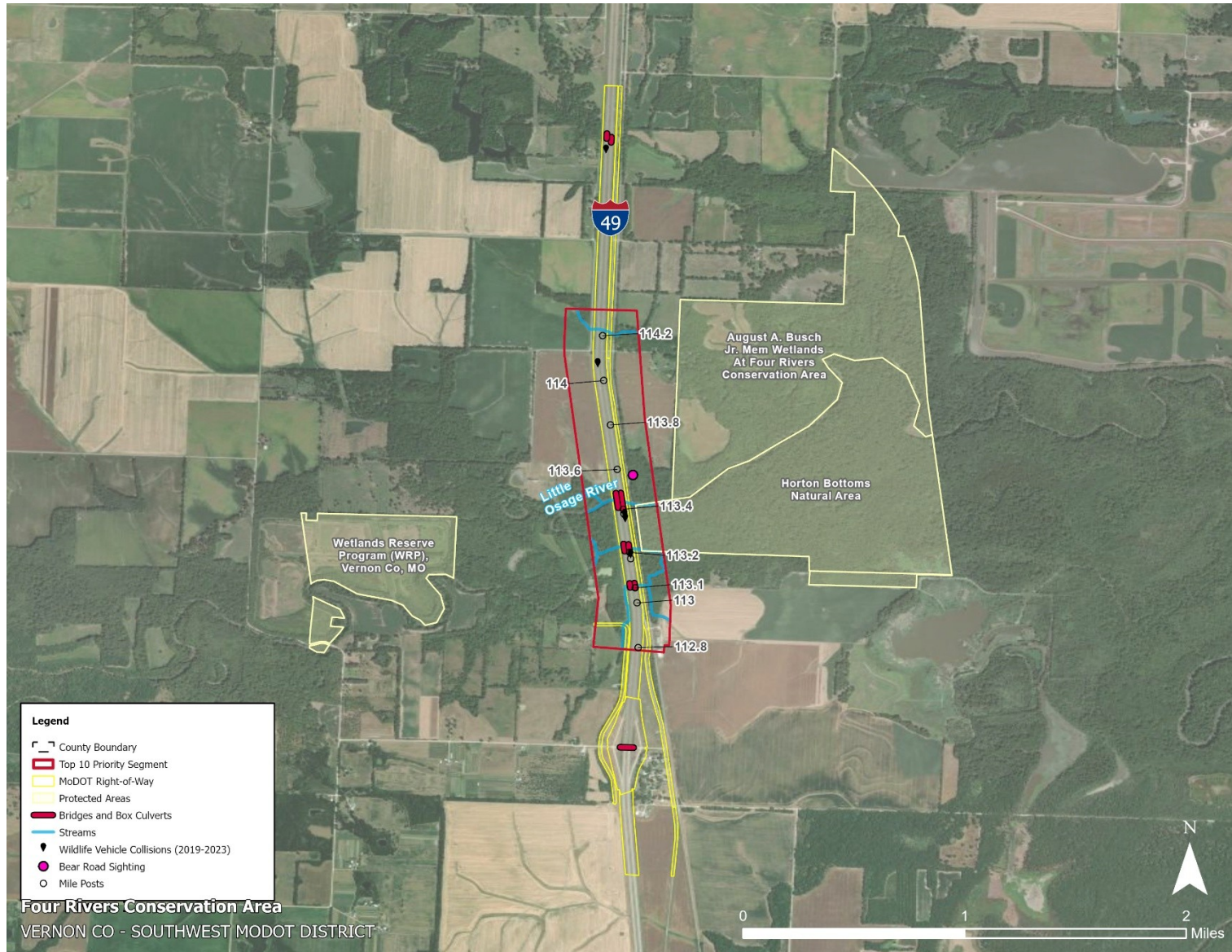


Figure 6-17: Four Rivers Conservation Area Overview Map, Horton Bottoms.



6.3.2 Recommendations

The average combined crash rate for the two portions is 0.46 wildlife crashes per mile per year, which is higher than statewide average of 0.10 crashes per mile per year. This is a lower crash rate when compared to some of the other Top 10 which varied from 0.2 to 1.20 crashes per mile per year. However, the presence of protected riparian forests and potential habitat for 18 of the Study's priority species throughout and adjacent to the Four Rivers Conservation Area elevated the importance of protecting connectivity and minimizing WVCs within this Top 10 segment.

In the three-mile-long Douglas Branch Conservation Area portion, north and south-bound traffic travel on bridges over the Marmaton River and the Douglas Branch. These bridges currently facilitate some wildlife movements and have the potential to support additional wildlife movements with the use of wildlife guide fences. Retrofit recommendations for the bridges are to place wildlife fencing to the north and south, with additional fencing installed along the interstate, between the bridges. The Douglas Branch retrofit would require a total of 14,836 feet of fence for both sides of the highway (2.8 miles in total, 1.4 straight miles along highway). The Marmaton River retrofit would require a total of 6,622 feet of fence (1.25 miles of fence in total, 0.63 straight miles along highway).

The Horton Bottoms Natural Area portion, located north of the Douglas Branch Conservation Area, is 1.5 miles long and contains three bridges, one culvert, and multiple opportunity areas for funneling wildlife below the road. The surrounding landscape is water-filled, with rivers and riparian wetlands throughout. The Horton Bottoms Natural Area lies to the east of the Top 10 segment, along with the August Busch Jr. Memorial Wetlands within the Four Rivers Conservation Area. The west side of the highway is privately owned; however, the Little Osage River runs parallel to the highway, which limits the potential for development. A Wetlands Reserve Program Easement lies 0.6 miles to the west.

The recommended wildlife fences would tie together the three existing bridges over the Little Osage River and its overflow channels. A WVC involving an American black bear was recorded within the Horton Bottoms Natural Area portion, suggesting that black bear range has expanded into the region and thus black bear-specific recommendations need to be considered within proposed wildlife mitigation methods. Therefore, the fences recommended for this area have been extended beyond the limits of other recorded WVCs in order to help funnel black bears to the crossing structures. Likewise, during the field investigations at this site, turtle carcasses were observed on the roadway near the bridge, likely due to females attempting to lay eggs on the highway berm. The proposed wildlife fence cell openings would be less than three inches high and four inches wide, to prevent turtles from getting through and accessing the road. The total linear footage for fences in this Top 10 segment would be 22,841 feet (4.33 miles, 2.16 straight miles along the highway).

Retrofitting the existing bridges with fencing in this location is somewhat challenging due to a dirt frontage road (Outer Road 49) and railroad corridor paralleling the east side of IS-49. Wildlife exclusion fencing should be placed along the ROW fence with ample space at the entrances for wildlife to approach the bridges after crossing these two transportation lines, or after they've

moved under the highway. Likewise, maintaining openness under the bridges is critical for wildlife movement, due to the challenges presented by the existing infrastructure.

6.3.2.1 IS-49 MARMATON RIVER BRIDGES – MP 108.01

These bridges are perfect de facto wildlife crossing structures: they are high (at least 15 feet) and long (possibly over 400 feet), accommodate a river, and have wide terrestrial benches to allow for wildlife movement (**Figure 6-18**). There was ample evidence of white-tailed deer movement along the river under these bridges at the time of the field investigation. However, WVCs involving deer have also been reported within 500 feet of the bridges. Placement of the recommended fences on all four corners address areas where reported WVCs have occurred and thus would help to prevent future crashes.

Figure 6-18: Marmaton River Bridges at MP 108.01.



Short Term Actions

Woody vegetation has grown up around the base of the bridge and between the small trees and large rock-concrete rip rap, causing difficulty when accessing the bottom of the bridges. Woody vegetation should be trimmed down to the ground and stumps should be removed on a yearly basis.

Retrofit Infrastructure

Wildlife exclusion fencing (with accompanying escape ramps and gates) should be placed off the bridge abutments in every direction. This fence is not just for mammals, but will need to exclude turtles, meaning cell openings would be less than three inches high and four inches wide so a turtle could not get through it.

- Fencing – 6,922 feet
 - Northeast Fence – 1,356 feet
 - Northwest Fence – 1,402 feet
 - Southeast Fence – 2,032 feet
 - Southwest Fence to where Southeast Fence ends – 2,053 feet.

- North Median Fence – 43 feet
- Escape Ramps – Four
 - Two at the north fence attachment to the north bridge abutments or midway within both of the north fence lines, and two on the south line fence.
- Gates – Four near bridge corners to allow for vegetation maintenance.

Infrastructure Solutions

The southbound bridge, built in 1969, is reaching the end of its effective life. The decking and siding of the bridge are noticeably deteriorating, and the bridge should be replaced soon. The new bridge should be as long or longer than the current bridge and should include wildlife exclusion fencing to guide wildlife to the bridge, if not already present (**Figure 6-19**).

Figure 6-19: Example of wildlife fencing tying to the bridge abutments. Picture taken on IS-25 in Douglas County, Colorado.



6.3.2.2 IS-49 DOUGLAS BRANCH BRIDGES – MP 109.53

This pair of bridges, like the Marmaton bridges, are perfect de facto wildlife crossing structures, due to bridge height, length, accommodation of a creek, and wide terrestrial pathways (**Figure 6-20**). Only one reported WVC has occurred within 500 feet of the bridge; however, there was an American black bear crash sighting in 2022. Dispersing black bears would likely not know the landscape well enough to find this bridge, increasing the risk of future black bear WVCs. Since the Douglas Creek Conservation Area provides important wildlife habitat and is located along the west side of the highway in this area, adding fencing to guide wildlife below the bridge in order to move to and from the Conservation Area would help white-tailed deer, black bear, and other priority species with potential to occur in the area.

Figure 6-20: Douglas Branch Bridges at MP 109.53.



Retrofit Infrastructure

Wildlife exclusion fencing (with accompanying escape ramps and gates) should be placed off the bridge abutments in every direction. Fencing in these locations will address 10 out of the last 12 WVCs in the area, resulting in an 85 percent crash reduction.

- Total Fence – 15,919 feet
 - Southwest Fence – 5,312 feet from bridge south to E Indian Line Road
 - Southeast Fence – 5,124 feet from bridge south to E Indian Line Road
 - Northwest Fence – 2,712 feet to E Gray Road
 - Northeast Fence – 2,690 feet to E Gray Road
 - North Median Fence – 39 feet
 - South Median Fence – 42 feet
- Escape Ramps – Ten
 - Six on south fences
 - Two at bridge abutments
 - Two at south fence ends
 - Two in the middle for both sides of highway fences
 - Four on north fences. Two at bridge abutments and two at fence ends
- Gates – Seven
 - Four at all corners of the bridge
 - One on east side of northeast fence, next to County Road 1463
 - Two at end of south fence near E Indian Line Road, one on each side

6.3.2.3 IS-49 FAR SOUTH OSAGE OVERFLOW BRIDGES – MP 116.76

These bridges are approximately 110 feet long. The bridges span overflow areas of the Little Osage River and are typically dry outside of periods of flooding. The existing area under the bridges is perfect for wildlife. Signs of white-tailed deer use were noted during the field investigation.



Retrofit Infrastructure

- Total Fence – 2,770 feet
 - Southeast Fence – 1,366 feet
 - Southwest Fence – 1,308 feet
 - North Median Fence – 49 feet
 - South Median Fence – 47 feet
- Escape Ramps – Two placed at bridge abutments, but negotiable as to where the best location would be
- Gates – One at each corner of the bridge abutments

6.3.2.4 IS-49 SOUTH OSAGE OVERFLOW BRIDGES – MP 109.53

These bridges span an area of intermittent water flow from flooding of the Little Osage River. They are approximately 115 feet long and extend high above the landscape. Fence lines would connect from these bridges to the bridges both north and south of this location.

Retrofit Infrastructure

Add fences to all bridge abutments and median.

- Total Fence – 1,634 feet
 - Southwest Fence – 789 feet
 - Southeast Fence – 750 feet
 - North Median Fence – 51 feet
 - South Median Fence – 44 feet
- Escape Ramps – Two placed on south abutments
- Gates – One at each corner of the bridge south sides

6.3.2.5 IS-49 OSAGE RIVER BRIDGES - MP 113.42

These bridges are so long (approximately 380 feet long) they could be considered viaducts that span the floodplain under normal annual conditions of the Little Osage River (**Figure 6-21**). The 100-year floodplain is much wider, thus requiring additional bridges to the south and a culvert to the north. Although the bridges and highway are perched above the landscape, two white-tailed deer WVCs were recorded to the south of the bridge and a black bear was killed in a WVC to north of the bridge. Several red-eared slider (*Trachemys scripta elegans*) turtle carcasses were noted on the edge of the roadway near the bridge during the field investigation. Wildlife will need exclusion fences to guide them to the bridged area to move beneath IS-49. This is especially true for black bears, which are not common in this area and would benefit from fences to guide them to the bridge opening. Fences would be placed along the ROW fence line. The fences connecting to the bridge abutments should fan out, leaving a wide-angle approach to the bridge.

Figure 6-21: Osage River Bridges at MP 113.42.



Retrofit Infrastructure

- Total Fence – 8,519 feet
 - Northwest Fence to E Chouteau Road – 3,357 feet
 - Northeast Fence to E Chouteau Road – 3,352 feet
 - Southwest Fence to South Osage Overflow Bridge NW corner – 869 feet
 - Southeast Fence to South Osage Overflow Bridge NE corner – 855 feet
 - North Median Fence – 41 feet
 - South Median Fence – 44 feet
- Escape Ramps – Eight
 - One on each bridge abutment corner for the Osage River Bridge
 - North corners of the South Osage Overflow Bridge
- Gates – Six
 - Four on all corners of the Osage River Bridges
 - Two on north corners of South Osage Overflow Bridges corners

6.3.2.6 RECOMMENDATIONS SUMMARY

A summary of the proposed mitigation is included in **Table 6-13** and depicted in **Figure 6-22** and **Figure 6-23**.

Table 6-13: Four Rivers Conservation Area Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Douglas Branch Conservation Area				
Marmaton River Bridges – A0337 & A2615 	108.1	Trim down woody vegetation; remove stumps	Place fence lines off of each corner of the bridge abutment. South fences are about 2,000+ feet. North fences are about 1,400 feet each. Place four gates at all corners of the fence near the bridge to allow for maintenance equipment. Add four escape ramps.	Southbound traffic bridge (west bridge) is 56 years old and will need replacement or heavy repair or decking – make adjustments during that project.
Douglas Branch Bridges – A7979 & A2614 	109.6	None	Place fence off of north side of bridge and extend about 2,700 feet; south fence extends about 5,280 feet. Place 10 escape ramps and seven gates.	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Horton Bottoms Conservation Area				
Far South Osage Overflow Bridges – B0560 & A2631 	113.1	None	Place exclusion fence off of bridge abutments and extend south about 1,310 feet. Add two escape ramps and two gates.	None
South Osage Overflow Bridges – B0559 & A2630 	113.2	None	Place exclusion fence off of all corners of the bridges and extend about 896 feet each. Add two escape ramps and two gates.	None



Missouri Statewide Wildlife Vehicle Collision Study Alternatives Analysis and Recommended Improvements

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Osage River Bridges – B0558 & A2629 	113.4	None	Place exclusion fence off of all corners of the bridge. Extend fence about 3,350 feet off north end and 860 feet off the south end, to next bridge. Add eight escape ramps and six gates.	None

Figure 6-22: Four Rivers Conservation Area, Douglas Branch, Mitigation Summary Map.

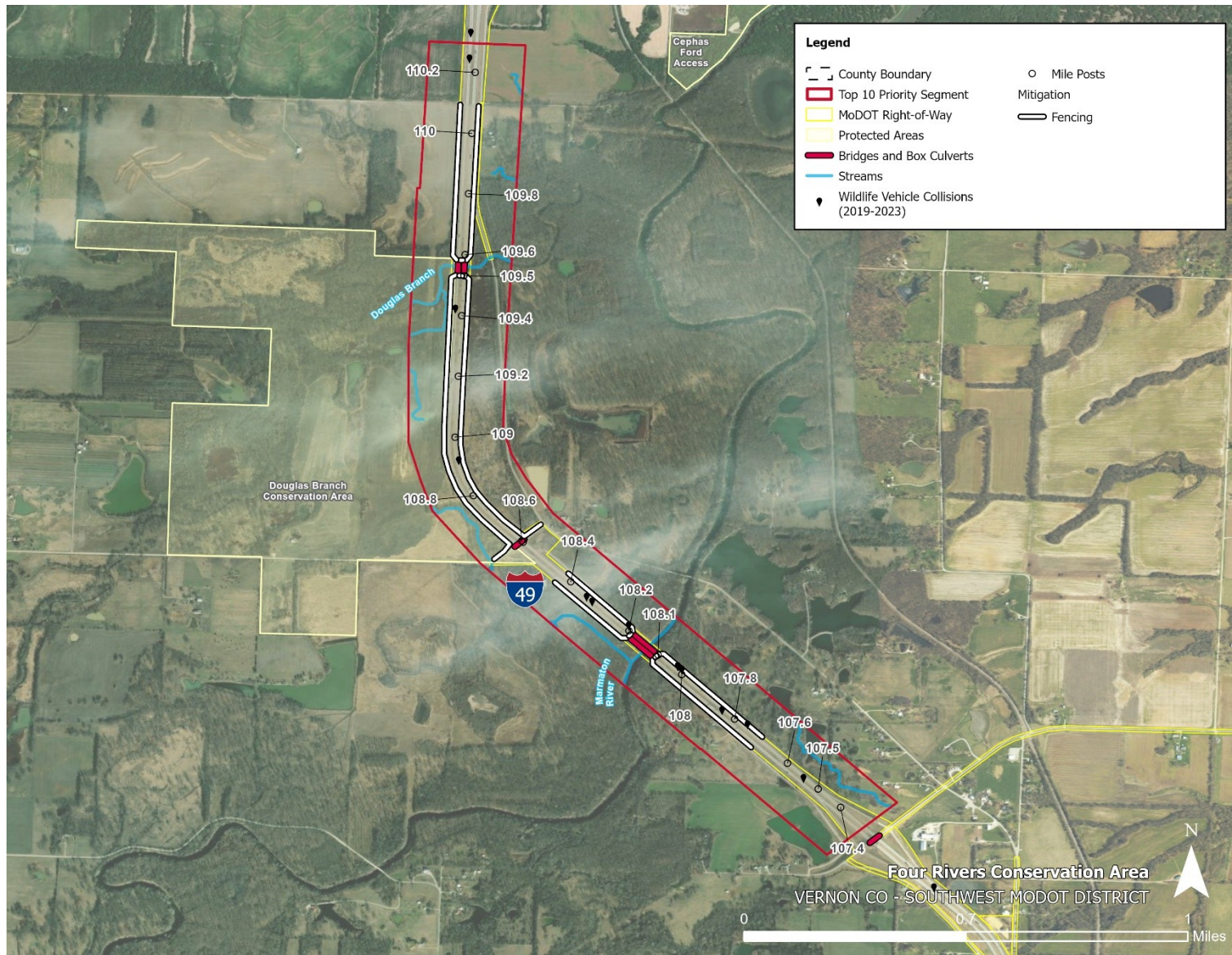
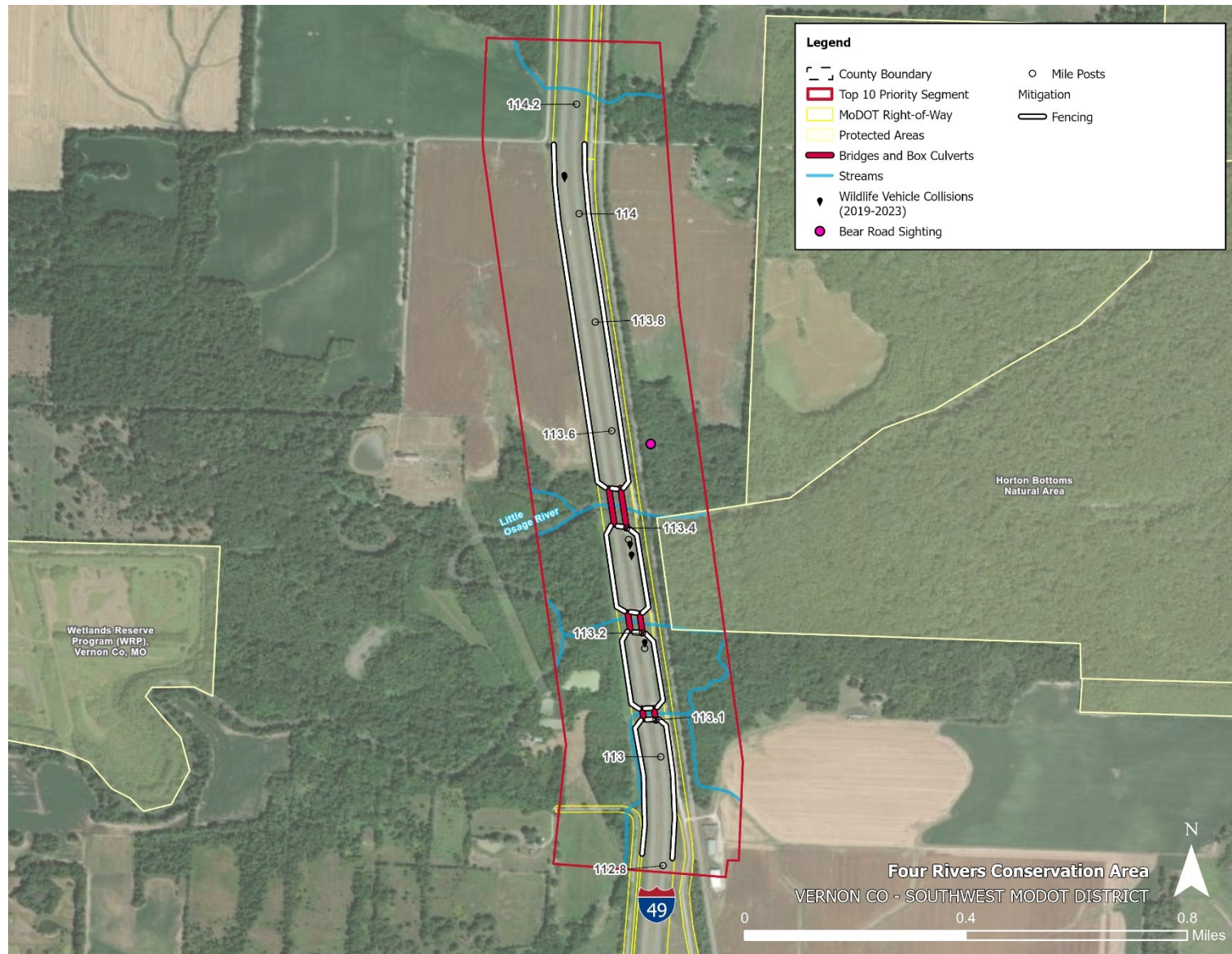


Figure 6-23: Four Rivers Conservation Area, Horton Bottoms, Mitigation Summary Map.





6.3.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 2.48, with a payback period of 20.17 years.

Table 6-14: Four Rivers Conservation Area Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	35,764 ft	\$30 per linear foot	\$1,072,920
Gates	17	\$1,500	\$25,500
Escape Ramps	22	\$22,000	\$484,000
Materials Total	--	--	\$1,582,420
Maintenance	50 years	\$1,000 per year	\$50,000
Grand Total	--	--	\$1,632,420

Table 6-15: Four Rivers Conservation Area WVC Costs Based on 2019-2023 Crash Data.

Crash Types	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO crashes	15	\$15,956	\$239,340	--
Minor Injury	1	\$204,700	\$204,700	--
Serious or Disabling Injury	0	\$787,600	0	--
Total Costs	--	--	--	\$444,040
Total Costs Per Year	--	--	--	\$88,808

Table 6-16: Four Rivers Conservation Area Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	$(88,808 + (2,000 \times 3.2)) \times 0.85 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	$1,582,420 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$4,046,340	\$1,632,420	2.48	20.17 years



6.4 Wappapello Reservoir

6.4.1 Project Overview

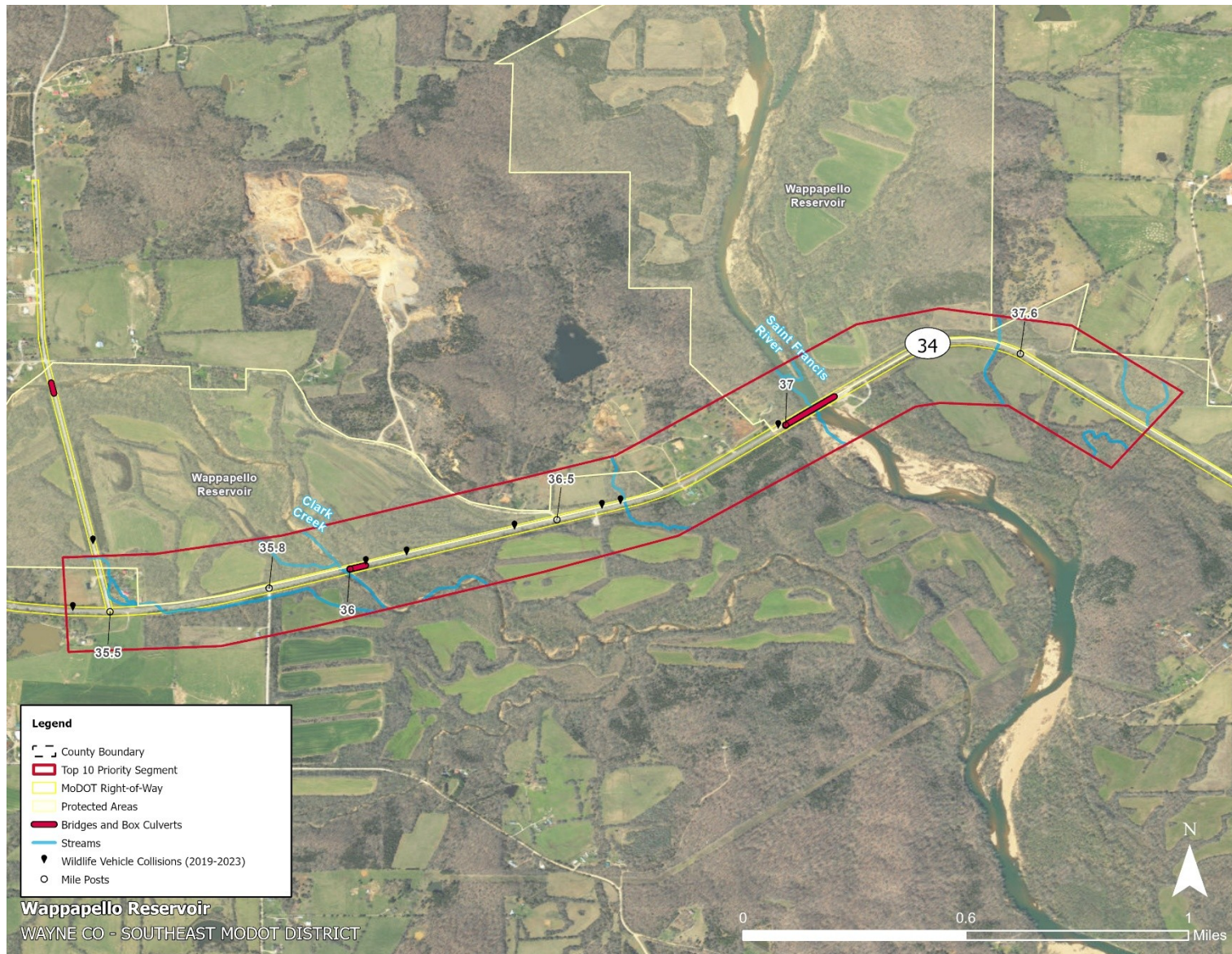
The Wappapello Reservoir Top 10 segment is located northwest of Greenville, Missouri, along Missouri State Highway (MO)-34 in a lowland area of riparian forests that border the St. Francis River, which flows from the north to the south. The reservoir lies to the north of MO-34. Much of the land adjacent to the highway on both sides is owned and managed by the USACE, with some private lands in the upland areas. The forested areas are interspersed with smaller agriculture plots. This area is situated within a larger landscape of rivers and riparian forests, with the Mark Twain National Forest just under 5 miles to the south and Sam Baker State Park to the north. The area is a key connection to this system of federal and state protected lands and waterways. In addition, the Ozark Trail follows the river and crosses beneath the St. Francis River bridge.



Table 6-17: Wappapello Reservoir Description and Criteria

Name: Wappapello Reservoir	
MoDOT District: Southeast	
County: Wayne	
Road and Mile Posts: MO-34 MP 35 – 38	
Total Miles: 3	
STIP Description: Bridge rehabilitation over Clarke Creek. Project involves bridge A1300.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	7
Wildlife Crashes per Mile per Year	0.47
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	39%
<i>Ecological</i>	
AADT	3,152
Occupied Habitat	Up to 5 priority species known to occur.
Predicted Suitable Habitat	Up to 18 priority species including: Kirtland's snake, black-tailed jackrabbit, eastern tiger salamander, American badger, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle.
MDC CCS Management Tiers	Saint Francis River – Tier 2, Clark Creek – Tier 3, Mudlick Glade/Woodlands – Tier 3, St. Francois Knobs Priority Forest Landscapes – Tier 3
Named Streams	Saint Francis River, Clark Creek
Bridges and Culverts	2 bridges
<i>Feasibility</i>	
Land Use	26 – 27% Developed
Protected Areas	Wappapello Reservoir
<i>Qualitative Review</i>	
Constructability	3
Land Use	3
STIP Rating	2

Figure 6-24: Wappapello Reservoir Overview Map.



6.4.2 Recommendations

Five of the seven wildlife-related crashes recorded in this Top 10 segment occurred within 700 feet or less of the three existing bridges and culverts in the area. The two bridges already accommodate white-tailed deer and other wildlife. Since the AADT in this area is 3,152 and the WVC crash rate is not high, the majority of recommendations are minimal.

Retrofitting is recommended for the St. Francis bridge. This long and very high bridge is a prime place to direct deer and other wildlife to cross beneath MO-34. Overall, the recommendations at this bridge are to improve wildlife use of the bridged area and to warn drivers of the dangers of WVCs as they approach. This includes placing approximately 650 feet of wildlife exclusion fence on the west side of the bridge, and 1,050 feet of fence to the east to direct wildlife to move beneath the bridge. A warning sign should be placed on the westbound lanes, just as motorists are entering the large curve in the approach to the St. Francis bridge area.

The Clark Creek bridge to the west side of the Top 10 segment does not need retrofit additions; the existing guard rail and other factors help to reduce wildlife movements over the road near here. There are two crashes nearby; however, the low traffic volume precludes fences in this area. Overall, this important connectivity area will need small additions to increase motorist safety and to guide wildlife to safe crossing opportunities beneath MO-34.

6.4.2.1 ST. FRANCIS RIVER BRIDGE – MP 37

The St. Francis River extends into the uplands during periods of high flow and runoff, thus the ownership by the USACE of much of the land, and easements on private land. The Ozark Trail occurs along the river area north and south. Small, short-term actions could make the area under the bridge more friendly to humans and wildlife for moving along the river on the trail. Overall, the recommendations are to improve wildlife use of the bridged area and to warn drivers of the dangers of WVCs as they approach.

Figure 6-25: St. Francis River Bridge at MP 37.



Short Term Action

On west side of the river, place a soil path through or over the concrete rip rap to allow humans and wildlife to move up and down slope. The state designated Ozark Trail moves beneath the bridge, and it is important to allow recreationists as well as wildlife to move through this area. Also, clear concrete from the path on the north side of the road, within ROW.

A static deer sign with flashing LED lights should be placed on the westbound lanes, at approximately MP 50.57 just as motorists are entering the large curve in the approach to the bridge area.

Retrofit Infrastructure

- Total Fence – 3,409 feet
 - Northwest Fence – 633 feet, extend to within 4 feet of culvert.
 - Northeast Fence – 1,046, extend to driveway at curve in highway.
 - Southwest Fence – 670 feet, extend to match fence on north side of road.
 - Southeast Fence – 1,060 feet, extend to driveway at curve in highway.
- Escape Ramps – Two, on east side fences at the boat ramp area, one on each side.
- Gates – Three, two on west side of bridge, placed on both sides of the road on the Ozark Trail that bisects the road just west of the bridge. One on east side at boat ramp driveway.
- Driveway Double Cattle Guard – One, for the Miles property driveway on north side of highway, west of the bridge.
- Roadway Double Cattle – One, double width for St. Francis River boat ramp entrance on east side.

This infrastructure would be placed where there is only one of the seven WVC crashes. Thus, the expected reduction of WVCs would be approximately 15 percent.

6.4.2.2 MO-34 BOX CULVERT – MP 36.6

This 5-foot high, 8-foot-wide box culvert was shown to have some water throughout during the field investigation. The culvert is a potential structure for use by small animals such as medium-sized mammals, frogs (which were found in the culvert), snakes, and other herpetofauna.

Figure 6-26: St. MO-34 Box Culvert at MP 36.6.



Short Term Action

Cut back trees and vegetative growth from the north side. The area should maintain some low brush vegetation to encourage continued use by amphibians.

6.4.2.3 MO-34 CLARK CREEK BRIDGE – MP 36

This bridge spans the creek and some upland areas, making it a perfect place for wildlife to move beneath the highway. The field investigation found evidence of white-tailed deer use of this area. Fish were also observed in the creek during the investigation. There were no reported WVCs within 500 feet of this bridge. The AADT is just over 3,000 vehicles per day. These two factors were considered when making recommended changes, which only entail clearing some vegetation in the area below the bridge. There were not enough WVCs nearby or a high enough AADT to warrant additional actions at this bridge.

Figure 6-27: St. MO-34 Clark Creek Bridge at MP 52.11.



Short Term Action

Clear some of the tree vegetation and larger brush along the creek near the bridge, to allow for a line-of-sight and for wildlife to move along the creek unimpeded. This would encourage use of the area below the bridge rather than above the road.

6.4.2.4 RECOMMENDATION SUMMARY

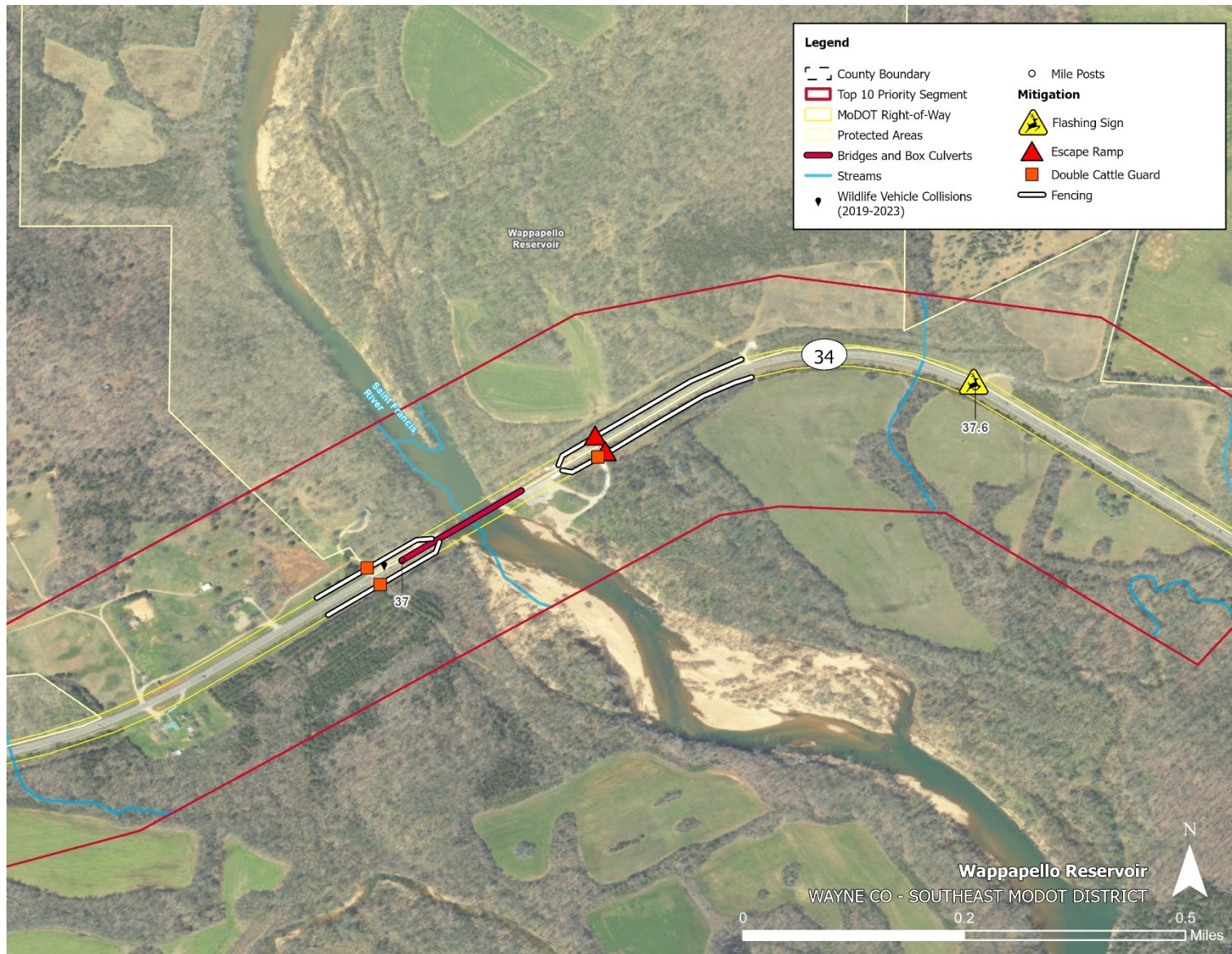
A summary of the proposed mitigation is included in **Table 6-18** and depicted in **Figure 6-28**.

Table 6-18: Roubidoux Creek Conservation Area Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
St. Francis River Bridge – F0111 	51.01	Place path through concrete rip rap on west side of bridge, and north and south of road. Also place warning sign on westbound lanes east of bridge.	Place fence off of each corner of the bridge abutment; about 650 feet on west side, and 1,050 feet on east side. Add three gates, two cattle guards, and two escape ramps.	None
MO-34 Box Culvert 	51.50	Cut back trees and vegetative growth from the north side. The area should maintain some low brush vegetation to encourage use by amphibians.	None	None
Clark Creek Bridge – A1300	52.11	Clear some of the tree vegetation and larger brush along the creek near the bridge.	None	None

Location		Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
					

Figure 6-28: Wappapello Reservoir Mitigation Recommendations.





6.4.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 0.60, with a payback period of 83.21 years.

Table 6-19: Wappapello Reservoir Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	3,409	\$30 per linear foot	\$102,270
Gates	3	\$1,500	\$4,500
Escape Ramps	2	\$22,000	\$44,000
Driveway Double Cattle Guards 16 foot	1	\$35,000	\$35,000
Road Double Cattle Guard 32 foot	1	\$78,000	\$78,000
Materials Total	--	--	\$263,770
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$313,770

Table 6-20: Wappapello Reservoir WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	7	\$15,956	\$111,692	--
Minor Injury	0	\$204,700	0	--
Serious / Disabling Injury	0	\$787,600	0	--
Cost For 5 Years	--	--	--	\$111,692
Average Cost Per Year	--	--	--	\$22,338

Table 6-21: Wappapello Reservoir Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	$(22,338 + (2,000 \times 1.4)) \times 0.15 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	$263,770 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$188,538	\$313,770	0.60	83.21 years



6.5 Whiteman Airforce Base and Knob Noster State Park

6.5.1 Project Overview

This Top 10 segment is within the Knob Noster State Park, which is east of Warrensburg and south of U.S. 50. Whiteman Airforce Base (AFB) is on the east side of this Top 10 segment. The roads included in Whiteman AFB and Knob Noster State Park are Missouri State Secondary Route (RT)-DD that runs east west through the park, and MO-23 which runs north-south between the park and the AFB. Knob Noster State Park is part of a riparian forest oasis of public and private lands along multiple creeks and rivers that lie in a north-south pattern between the AFB and Warrensburg.

The Clearfork River runs north-south across the RT-DD and meanders through Knob Noster State Park. McAdoo Creek runs from the west, beneath RT-DD and joins the Clear Fork south of the highway. The area between and near these water bodies had at least six reported WVC and the field investigation revealed a half dozen white-tailed deer carcasses below the highway in the ditch areas along RT-DD. The existing road is on a berm through the park, and the ROW fence is below the level of the highway and somewhat out of view of motorists.

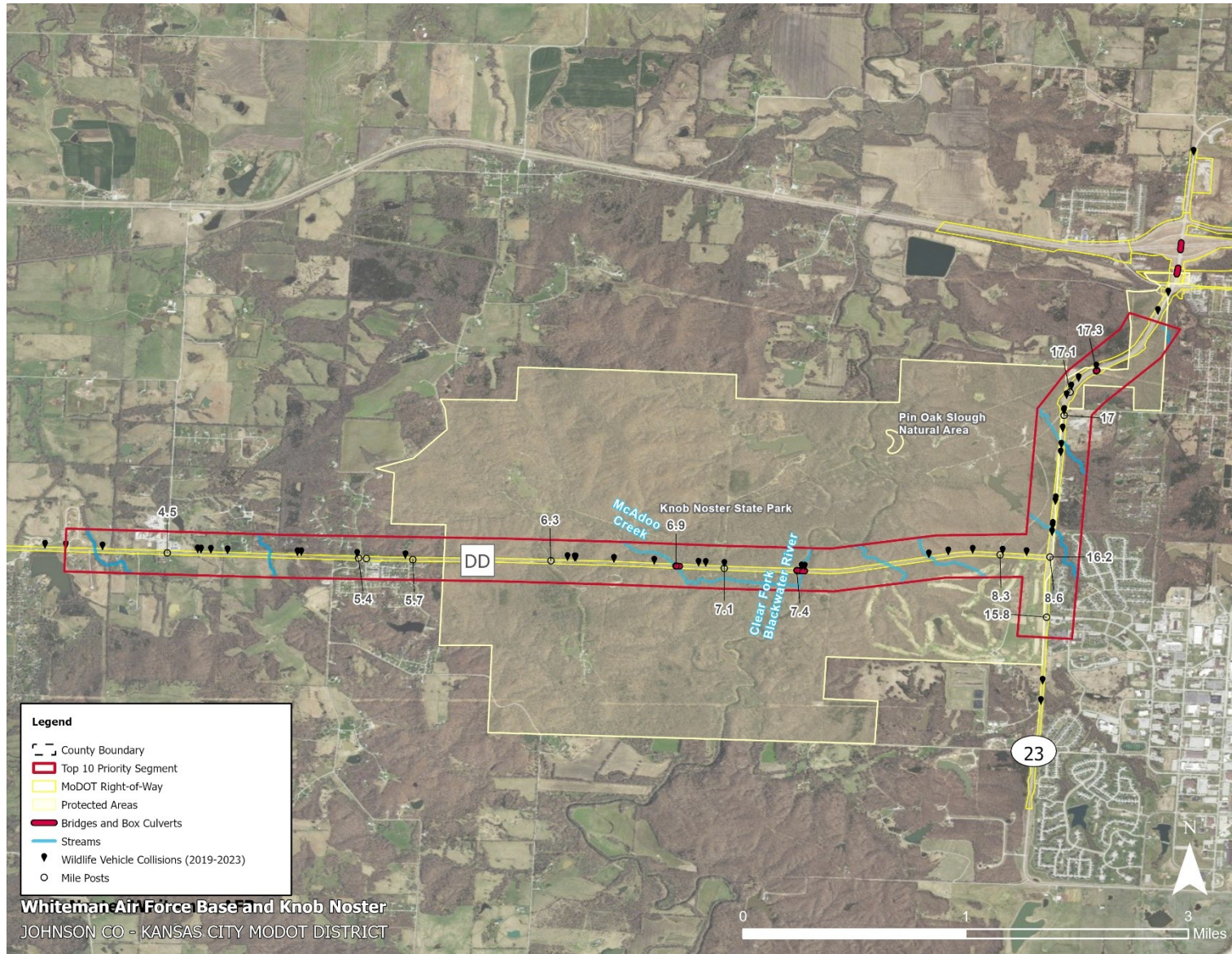


Missouri Statewide Wildlife Vehicle Collision Study Alternatives Analysis and Recommended Improvements

Table 6-22: Whiteman Airforce Base and Knob Noster State Park Description and Criteria

Name: Whiteman Airforce Base	
MoDOT District: Kansas City	
County: Johnson	
Road and Mile Posts: RT-DD MP 4.1 – 8.6 and MO-23 MP 15.6 – 17.6	
Total Miles: 6.5	
STIP Description: Pavement resurfacing, signal upgrades, and turn lane additions from MO-50 to RT-DD. Funding allocated for 2025.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	39
Wildlife Crashes per Mile per Year	1.2
Crashes with Fatality and/or Serious Injury	1
Percentage of All Crashes that are WVC	38%
<i>Ecological</i>	
AADT	5,400
Occupied Habitat	Up to 3 priority species known to occur.
Predicted Suitable Habitat	Up to 18 priority species including: black-tailed jackrabbit, eastern tiger salamander, American badger, Franklin's ground squirrel, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle..
MDC CCS Management Tiers	Clear Fork – Tier 4
Named Streams	McAdoo Creek, Clear Fork Blackwater River
Bridges and Culverts	2 bridges, 1 box culvert
<i>Feasibility</i>	
Land Use	30% Developed
Protected Areas	Knob Noster State Park
<i>Qualitative Review</i>	
Constructability	3
Land Use	3
STIP Rating	2

Figure 6-29: Whiteman Airforce Base and Knob Noster State Park Overview Map.



6.5.2 Recommendations

6.5.2.1 KNOB NOSTER STATE PARK

The developed nature of the west side of the Top 10 segment where the park ends will preclude any mitigation measures for wildlife. RT-DD stretches 2.8 miles across Knob Noster State Park. Mitigation measures here would have to accommodate all types of wildlife that may be present in the park and need to move across the road area; there is potential suitable habitat for 18 priority species. It will be important to protect wildlife and motorists from collisions with retrofit fences added to the McAdoo Creek and the Clear Fork River bridges, and a new wildlife underpass that can accommodate the SE 691st Road on the west side. A new wildlife crossing at SE 691st Road would accommodate campground and recreational traffic, recreationists, and wildlife.

A 1.5-mile fence along RT-DD tied to these two existing and one new structure would help to reduce WVCs and provide connectivity for a multitude of species. This 1.5-mile stretch had 10 reported WVCs over five years, equating to 1.33 wildlife crashes per mile per year. These combined potential uses of the underpass should help the search for funding sources.

6.5.2.2 WHITEMAN AIRFORCE BASE

This area is difficult to mitigate for the 14 WVCs reported on MO-23. The developed AFB to the east may have some use for some species, but it is likely a sink habitat, where animals that enter cannot find sufficient safe resources to survive and reproduce, and thus die. The state park on the west side of the highway would need connectivity provided for wildlife and ecosystem processes, such as water flow, but mitigating eastward from the park into this area is not a viable option. Therefore, fences on both sides of MO-23 would keep wildlife on the west side and possibly moving north-south, where there is better habitat. The AFB already has a 10 feet high chain link fence along its property boundary, both along the highway and eastward from the highway ROW. It appears white-tailed deer almost certainly are funneled by this fence to cross MO-23 at the corner of the fence. There were two reported crashes adjacent to the fence corner, and one approximately 200 feet to the south. This fence extends southward from the north property line, 0.5 miles along the AFB. A wildlife exclusion fence could be placed from the north terminus of the AFB fence northward one mile to the just past the curve in MO-23 to the north terminus area of Knob Noster State Park where there are power lines bisecting the highway. This would help keep deer and other wildlife off the road in areas where there is little wildlife habitat to the east, and where the curve in the road restricts motorists' line-of-sight, increasing the likelihood for WVCs. The west side of MO-23 fence would be a bit longer, starting from the intersection with RT-DD northward to the powerlines.

There is a north Whitman AFB culvert that is 10 feet high, 12 feet wide, and 120 feet long. There was standing water in it during the field investigation. White-tailed deer have been known to walk through standing water in culverts, but they prefer not to, and these structures have a much higher repel rate than dry culverts (Cramer and Hamlin 2015). However, this culvert is within the length limits of what white-tailed deer have been known to use and could be retrofitted with fence to encourage wildlife use.

6.5.2.3 SE 691ST ROAD NEW UNDERPASS – MP 6.29

Infrastructure Solutions

There are two options for a new underpass: it could serve as a multi-use underpass for the passage of vehicles and recreationists on SE 691st, or the underpass could be set just east of the current road and be solely for wildlife. A multi-purpose structure would limit wildlife use during the day but would provide full availability by night when human usage is lower. If the underpass served multi-purpose use, there should be multiple funding sources available.

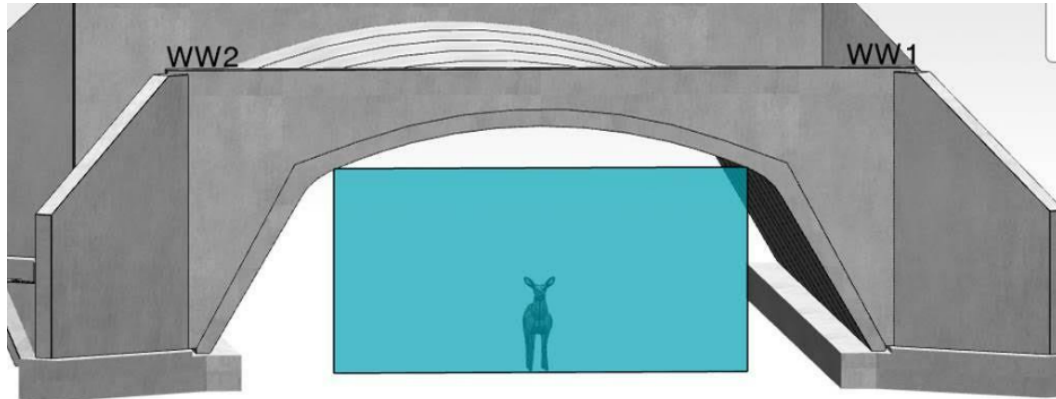
The structure should be high enough to accommodate recreational vehicles including tall campers, and park maintenance equipment. The wet environment in the area would limit the depth the road could be excavated to, and the structure would have to be fairly shallow in the landscape (not high).

Figure 6-30: Example of First Option for SE 691st Road at MP 6.29.



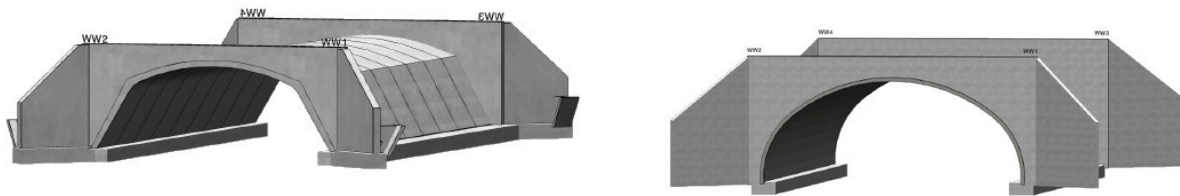
A second option would be an underpass solely for wildlife (with possible additional use by recreationists). This wildlife underpass would be to the east of the current SE 691st Road. Prefabricated structure estimates and installation estimates from Contech Solutions design team were provided for both potential underpasses; one to accommodate vehicles with recreational vehicles in tow, and one solely for wildlife. Below is a diagram of one solely for wildlife, a potential prefabricated arch underpass.

Figure 6-31: Example of Second Option for SE 691st Road at MP 6.29.



The option for a wildlife underpass is presented below with a multipurpose schematic for the existing road to tunnel beneath RT-DD.

Figure 6-32: Left is an arch underpass example for wildlife only, and right is an arch underpass for vehicles and wildlife.



The diagrams for these types of structures are provided in **Appendix I**.

- Total Fence – The lengths of fence needed for this structure have been included in the McAdoo bridge retrofits.
- Escape Ramps – Two, should be placed near the underpass abutments, or farther west on the fence line. The east side escape ramps are accounted for in the McAdoo retrofits.
- Gates – Two, should be placed at the structure to allow for maintenance activities and human movement.
- Driveway Double Cattle Guard – Four. If the future underpass accommodated SE 691st Road, there would need to be access ramps for entrance and exit onto RT-DD. These ramps would need additional double cattle guards.

Contech Solutions provided a preliminary quote for the costs of the underpass, whether it was multipurpose or wildlife-only. The materials cost is estimated at about \$421,500, and the total for the structure and the labor and excavation to place it under SH-DD was \$599,875.

6.5.2.4 RT-DD MCADOO CREEK BRIDGE – MP 6.86

The bridge over the creek is a perfect de facto wildlife crossing beneath RT-DD. There is aquatic and terrestrial connectivity.

Short Term Action

Make paths across the rip rap rocks beneath the bridge, either by placing soil on top of the rocks, or clearing a 3 to 10 foot wide path. This will also help any humans traversing the area beneath the bridge. This should be done on both sides of the creek.

Figure 6-33: RT-DD McAdoo Creek Bridge at MP 6.86.



Retrofit Infrastructure

- Total Fence – 7,897 feet.
 - Northwest Fence – 3,945 feet.
 - Southwest Fence – 3,952 feet.
- Escape Ramps – Four, place a ramp near where three WVCs were reported as crashes on the east side of SE 691st Road. Place the other three where MDC wildlife professionals believe are the best locations. It is suggested that at least one escape ramp be placed at the bridge where the fence meets an abutment.
- Gates - Four, to be placed at each bridge abutment corner to allow for maintenance equipment and other kinds of access.

6.5.2.5 RT-DD CLEAR FORK RIVER BRIDGE – MP 7.41

This bridge is long and high, and a perfect de facto wildlife crossing structure. The presence of a muddy terrestrial pathway along the river with many white-tailed deer tracks during the field investigation attested to the high use the area is already receiving.

Figure 6-34: RT-DD Clear Fork River Bridge at MP 7.41.



Short Term Actions

Vegetation management should continue at this bridge to allow full access to the structure.

At the east end, where the future wildlife exclusion fence will end, place static deer signs with flashing LED lights and solar power for both directions of traffic. The road is hilly on the eastern end of RT-DD and poor line-of-sight may be a contributing factor to the occurrence of WVCs. Drivers will need to be warned of the potential for collisions at the east fence ends.

Retrofit Infrastructure

Add wildlife exclusion fences to the bridge abutments in both directions to encourage use by wildlife. This is especially important to wildlife that may be unfamiliar with the area.

- Total Fence - 8,417 feet.
 - North Fence – 2,823 feet, place west to the McAdoo Creek bridges.
 - South Fence – 2,842 feet.
 - Northeast Fence – 1,368 feet.
 - Southeast Fence – 1,384 feet.
- Escape Ramps – Two, one near the State Park Road, and another toward Clear Fork River bridges.
- Gates – Seven. Four gates at the four corners of the bridge, two gates at the State Park Road on the north side of the highway, and one gate on the south side at the state park utilities drive.
- Driveway Double Cattle Guard – Three, one singular double cattle guard at the state park utility drive on the south side, another single wide double cattle guard at the road on the south side east of Clear Fork River.
- Road Double Cattle Guard – One, at NE 751st Road (the park entrance road on the north side).

6.5.2.6 MO-23 WHITEMAN AIR FORCE BASE

The AFB already has a 10 foot high chain link fence along its property boundary, both along the highway and eastward from the highway ROW. This fence extends southward from the north property line 0.5-mile along the base. A wildlife exclusion fence could be placed from the north terminus of the AFB fence northward one mile to the just past the curve in MO-23 to the north terminus area of Knob Noster State Park where there are power lines bisecting the highway. The west side of MO-23 fence would be a bit longer, starting from the intersection with RT-DD northward to the powerlines.

Figure 6-35: Existing AFB Fencing at MP 16.4.



The existing south culvert at approximately MO-23 S MP 33.6 can only accommodate small aquatic organisms.

Figure 6-36: South Culvert MO-23 at MPs 16.4.



The north Whitman AFB culvert is 10 feet high by 12 feet wide, and approximately 120 feet long, with a concrete bottom, see below.

Figure 6-37: North Culvert on MO-23 at MP 16.8.



Short Term Actions

The vegetation on the west side of MO-23 in the park comes very close to the highway. This reduces drivers' ability to see wildlife in the road, especially along the curve on the north end of MO-23. The vegetation should be trimmed back to the MoDOT ROW fence line to help reduce WVCs.

Retrofit Infrastructure

- Total Fence – 11,377 feet.
 - Northeast Fence – 5,352 feet.
 - Northwest Fence (west side of MO-23) – 6,025 feet.
- Escape Ramps – Six, place near areas where wildlife get in, and near fence ends.
- Gates – Five, place throughout fence to allow access to private lands and state park near cattle guards, so those who cannot cross guards safely can use gates.
- Driveway Double Cattle Guards – Eight, placed at all businesses and private residences
- Road Double Cattle Guard – One, place at park entrance on west side of MO-23

Expected reduction of WVCs to be approximately 60 percent.

6.5.2.7 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-23** and depicted in **Figure 6-38**, **Figure 6-39**, and **Figure 6-40**.

Table 6-23: Whiteman Airforce Base and Knob Noster State Park Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
SE 691st Road 	6.3	None	Place fence lines off of each corner of the future bridge abutments. See McAdoo description for fence lengths. Place gates on each side of highway near structure to allow for maintenance equipment.	Place a new multi-use underpass at the location of this road. It would accommodate wildlife, all types of RVs, and recreationists. Or place a smaller wildlife underpass to the east that would only accommodate wildlife and recreationists.
RT-DD McAdoo Creek Bridge – B0273 	6.86	Place soil path over rip rap or create a path thru.	Attach fence to west bridge abutment and extend 4,000 feet on the north and south sides of highway.	None
RT-DD Clear Fork River Bridge – B0272	7.41	Static warning signs with solar powered LED lights at east fence end	Extend fence off of the west abutments 2,824 feet to McAdoo Bridge, and place fence off east abutments 1,380 feet. Add two escape ramps, seven gates, and three double cattle guards.	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
				
MO-23 Whiteman Airforce Base 	15.6-17.6	Trim back vegetation along the entire length and back to the MoDOT ROW fence line.	Fence the stretch of MO-23 from the intersection of RT-DD northward for 6,072 feet. Place six escape ramps, five gates and nine double cattle guards.	None

Figure 6-38: Whiteman Airforce Base and Knob Noster State Park Mitigation Recommendations, West.

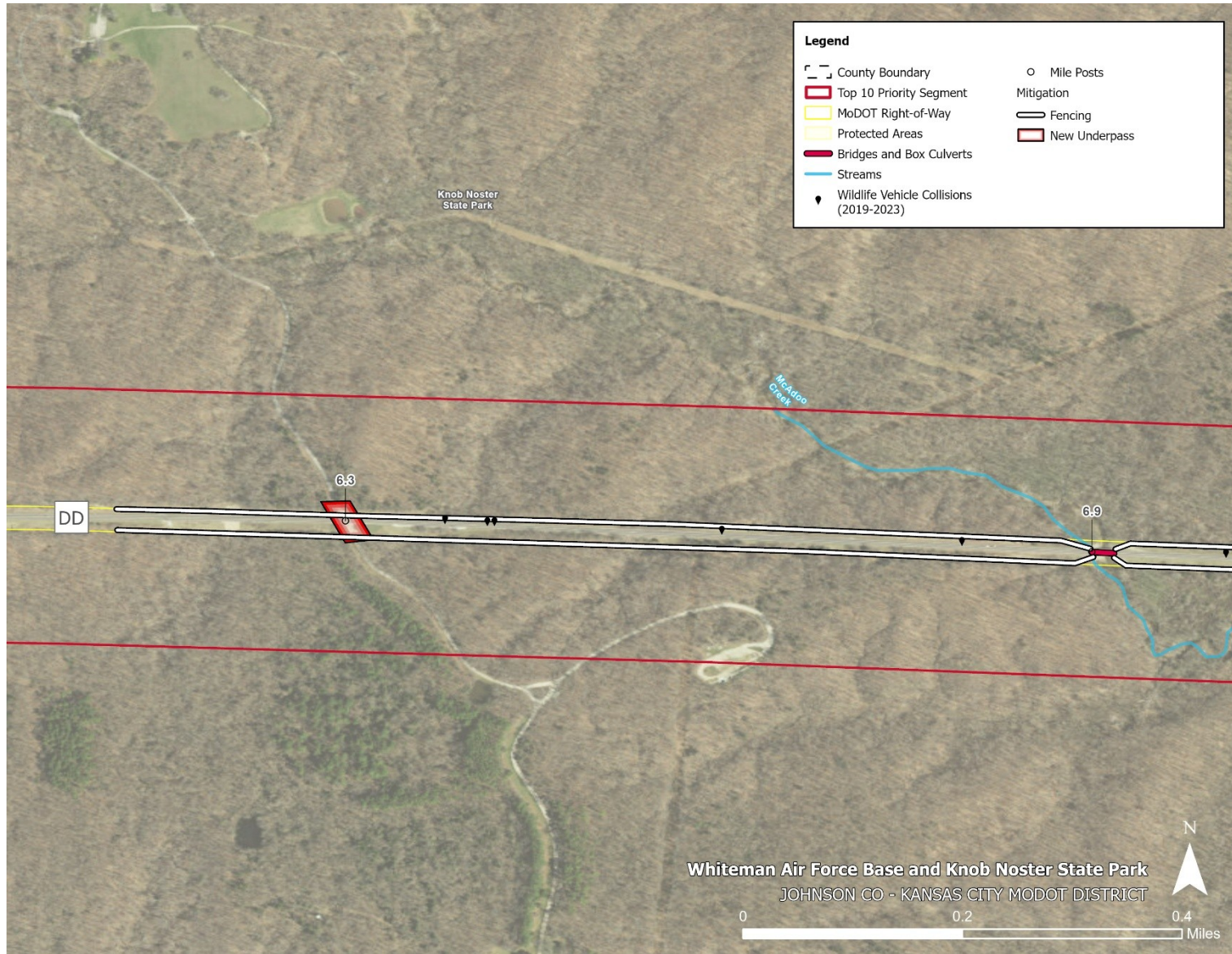
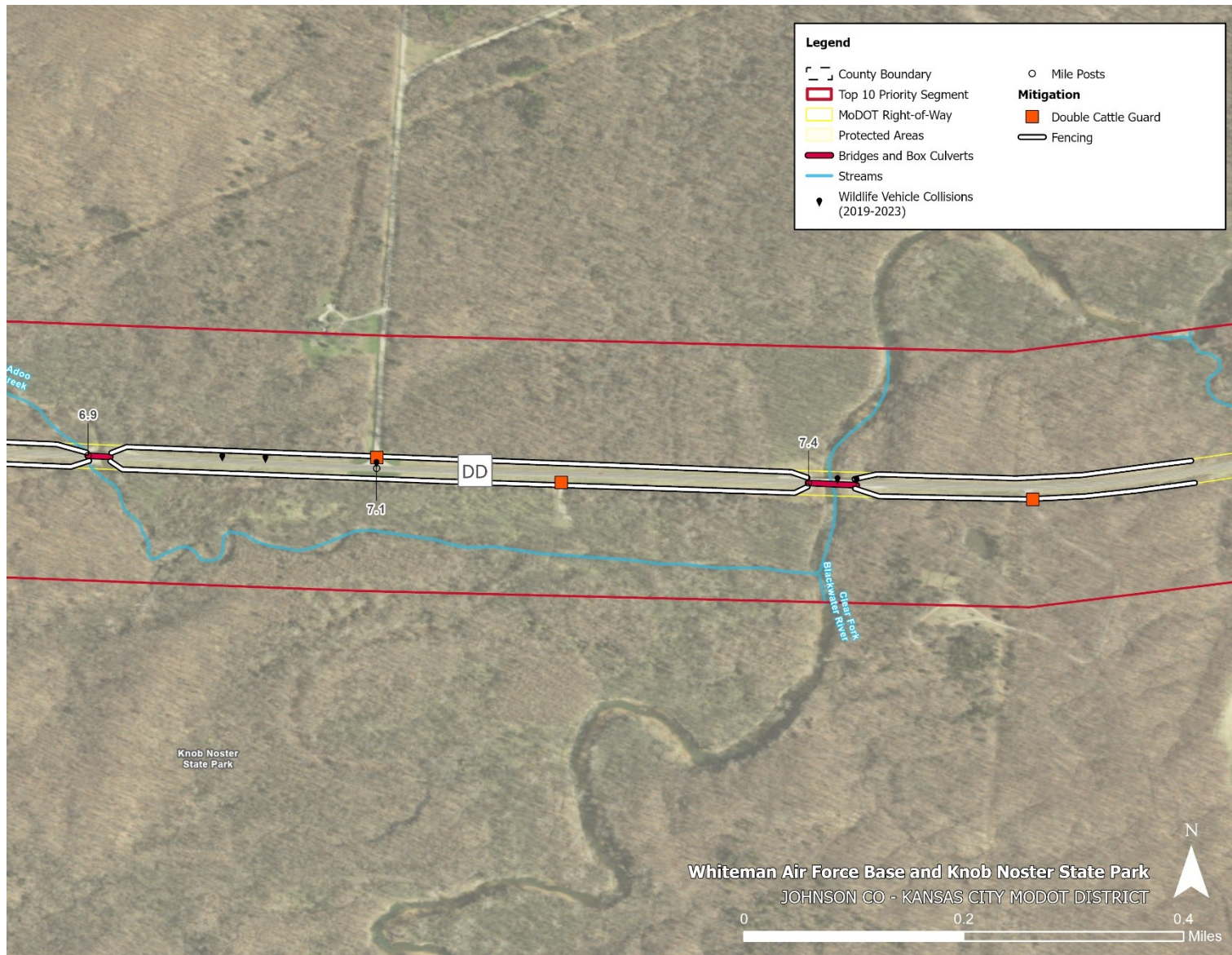


Figure 6-39: Whiteman Airforce Base and Knob Noster State Park Mitigation Recommendations, Center.



Legend

- County Boundary
- Top 10 Priority Segment
- MoDOT Right-of-Way
- Protected Areas
- Bridges and Box Culverts
- Streams
- Wildlife Vehicle Collisions (2019-2023)
- Mile Posts
- Mitigation**
 - Double Cattle Guard
 - Fencing

Knob Noster State Park

Whiteman Air Force Base and Knob Noster State Park
JOHNSON CO - KANSAS CITY MODOT DISTRICT

Scale: 0.3, 0.7 Miles



6.5.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 3.29, with a payback period of 15.18 years.

Table 6-24: Whiteman Airforce Base and Knob Noster State Park Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	27,691	\$30 per linear foot	\$830,730
Gates	16	\$1,500	\$24,000
Escape Ramps	8	\$22,000	\$264,000
Road Double Cattle Guard 16 foot	11	\$35,000	\$385,000
Road Double Cattle Guard 32 foot	2	\$78,000	\$78,000
Multipurpose Underpass	1	\$1,659,730	\$1,659,730
Materials Total	--	--	\$3,319,460
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$3,369,460

Table 6-25: Whiteman Airforce Base and Knob Noster State Park WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	36	\$15,956	\$574,416	--
Minor Injury	2	\$204,700	\$409,400	--
Serious / Disabling Injury	1	\$787,600	\$787,600	--
Cost For 5 Years	--	--	--	\$1,771,416
Average Cost Per Year	--	--	--	\$354,283

Table 6-26: Whiteman Airforce Base and Knob Noster State Park Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	$(354,283 + (2,000 \times 7.8)) \times 0.60 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	$599,875 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$11,096,496	\$3,369,460	3.29	15.18 years



6.6 Parma Woods Shooting Range

6.6.1 Project Overview

This Top 10 segment is northwest of Kansas City and includes Interstate 435 (IS-435) and MO-45. The southern end of the I-435 portion of the Top 10 segment is adjacent to the Missouri River. Parma Woods Conservation Area is located on the west side of IS-435, on the southern end of the Top 10 segment. Parma Woods provides protection for a diversity of wildlife, water flow to the Missouri River, and recreational value on both sides of IS-435. On the east side of IS-435, across from Parma Woods, MoDOT owns a large swath of land that includes Brush Creek and nearby wetlands. The wetness of this area makes development difficult, thus the existing landcover consists predominantly of intact, riparian forests. However, much of the land adjacent to the MoDOT property is privately owned and may be developed in the future. This area is quickly becoming heavily urbanized, leading to WVCs. A total of 59 reported WVCs occurred over five years throughout the 10-mile Top 10 segment. Due to the increased urbanization and existing infrastructure, options for directing deer and other wildlife to existing bridges and culverts or suitable locations for building new structures are limited. There are two existing culverts under IS-435 south of MO-45 that facilitate water conveyance through the area.



Missouri Statewide Wildlife Vehicle Collision Study Alternatives Analysis and Recommended Improvements

Table 6-27: Parma Woods Shooting Range Description and Criteria

Name: Parma Woods Shooting Range	
MoDOT District: Kansas City	
County: Platte	
Road and Mile Posts: IS-435 MP 51.5-55.5 and MO-45 MP 6 –10	
Total Miles: 10	
STIP Description: Payment to KDOT for column repair on IS-435 from 0.16 miles south of Northwest River Road and 1.17 miles north of Wolcott Drive. Project involves twin bridges A3289. Add southbound left turn lane and northbound right turn lane at Jones-Meyer Road. Bridge and culvert improvements at various locations in the urban Kansas City District. Project involves bridges A2087, P0812, A3301, A3980, A3329, N0327, N0360 and N0836. Funding allocated for 2026.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	59
Wildlife Crashes per Mile per Year	1.18
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	21%
<i>Ecological</i>	
AADT	15,014
Occupied Habitat	Up to 2 priority species known to occur.
Predicted Suitable Habitat	Up to 19 priority species including Kirtland's snake, black-tailed jack rabbit, eastern tiger salamander, American badger, Franklin's ground squirrel, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least Weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle
MDC CCS Management Tiers	Iaton/Weston – Tier 3 Missouri River – Tier 3 Parma Woods – Tier 3 Parma Woods – Tier 4
Named Streams	Pearl Branch, Naylor Creek, Ellis Branch, Brush Creek, Brown Branch
Bridges and Culverts	7 bridges 2 box culverts
<i>Feasibility</i>	
Land Use	22 – 26% Developed
Protected Areas	Wetland Reserve Program, Nearby Long Branch State Park
<i>Qualitative Review</i>	
Constructability	2.33
Land Use	2
STIP Rating	3

Figure 6-41: Parma Woods Shooting Range Overview Map, North.

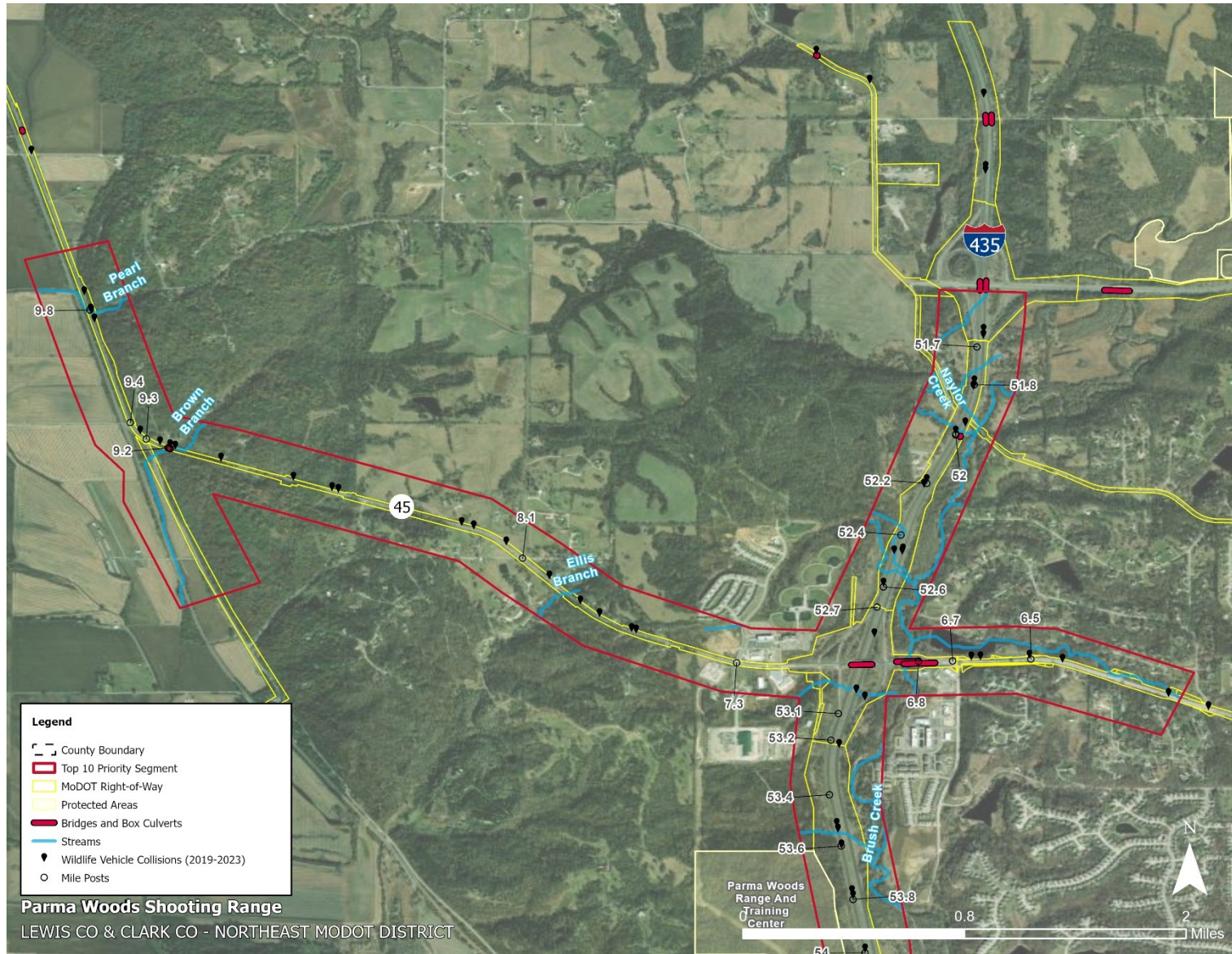
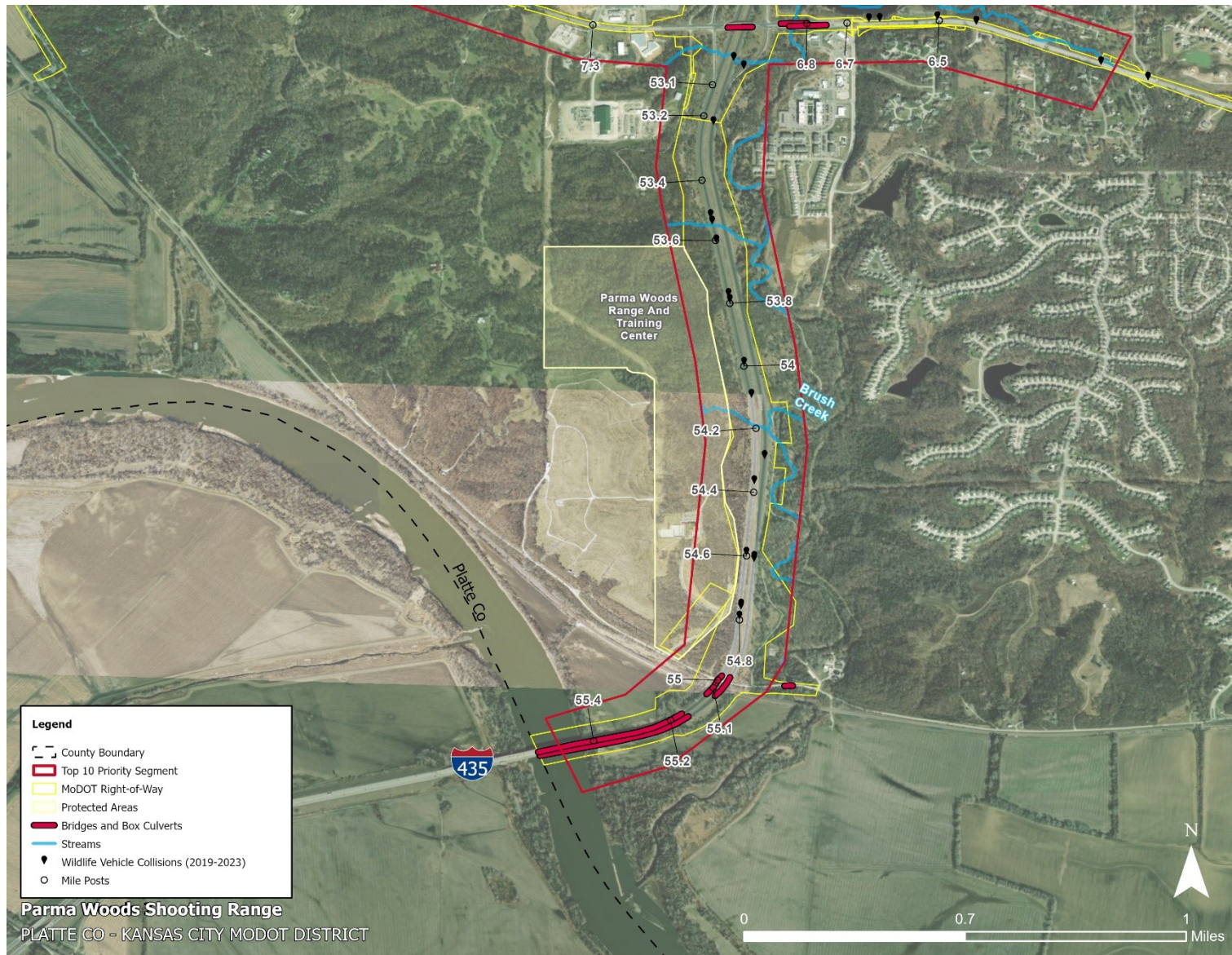


Figure 6-42: Parma Woods Shooting Range Overview Map, South.



6.6.2 Recommendations

Recommended mitigation measures for this Top 10 segment include approximately 1 mile of wildlife exclusion fence on both sides of the highway along IS-435, extending north from the River Road bridges. The fencing will help keep wildlife off the highway and guide them to the pair of existing IS-435 bridges over River Road and to two existing culverts that direct water flow out of Parma Woods Conservation Area. The recommendations also include adding approximately 1,900 feet of fence to the existing ROW fence along the east side of IS-435 at the exit ramp to MO-45. Additional recommendations include placing a static wildlife sign with flashing LED lights on MO-45, just before the hill as westbound traffic approaches the traffic circle at the West Brink Meyer Road/ County Road to the south. Future recommendations include the replacement of the Naylor Creek Culvert under IS-435 with a larger set of structures.

6.6.2.1 IS-435 BRIDGES OVER RIVER ROAD – MP 55.04, S MP 0.53

Short Term Actions

Maintain soil pathways along the River Road pavement to provide deer and other wildlife pathways, especially when the conditions are snowy and icy. It may be beneficial if trash was cleared out along the River Road ROW under the bridge.

Figure 6-43: Bridges over River Road at MP 55.04, S MP 0.53.



Retrofit Infrastructure

Placing wildlife exclusion fences at the IS-435 bridges and River Road to channel deer to move beneath the interstate at the bridges. Fence would also funnel wildlife to the two existing culverts to the north of the bridges. The Brush Creek Culvert is 6 feet high and 8 feet wide, with an immense drop off on the east side. While this structure allows water flow to Brush Creek, it is not ideal for wildlife but may provide some connectivity for any wildlife that can navigate through. MoDOT records indicate the presence of another culvert north of the Brush Creek Culvert, but the culvert was not found during the field investigation. This culvert, while it passes water, could also potentially allow for wildlife passage.

Figure 6-44: Brush Creek Culvert.



- Total Fence – 10,089 feet
 - Northeast Fence – 5,060 feet, placed on ridge abutments and extended from the abutment to just north of the existing box culvert at North MP 54.23.
 - Northwest Fence – 4,980 feet.
 - North Median Fence – 49 feet.
- Escape Ramps – Four, two on each side of the highway.
- Gates – Two, to access the bridge area and for mowing, placed on the north side of the bridges.

6.6.2.2 IS-435 BOX CULVERT – MP 54.23

Infrastructure Solutions

Replace the box culvert with a new bridge set or a set of larger culverts with an open median. The current culvert is 6 feet high and 8 feet wide and extends the length of the entire highway width (approximately 330 feet), with no opening in the median. It accommodates water flow to Brush Creek on the east side of IS-435. The new structures should be large enough to accommodate both the water flow and pedestrian access from the Brush Creek Trail which extends north/south on the east side of IS-435.

Figure 6-45: IS-435 Box Culvert MP 54.23.



6.6.2.3 MO-45 BRIDGE OVER IS-435 – MP 7.0

This area is difficult to mitigate due to heavy development along MO-45 and County Road – Brink Meyer Road to the east. However, a bridge on MO-45 that accommodates Brush Creek to the east of IS-435 could accommodate wildlife moving in the area.

Retrofit Infrastructure

Place a wildlife exclusion fence from the abutment on the west side of the south bridge (for eastbound traffic), down to the existing ROW fence along the exit ramp with the goal of allowing wildlife access to Brush Creek from the east while preventing them from getting onto IS-435. This mitigation will help keep IS-435 safer for motorists but does little for MO-45 safety.

- East Side of Northbound IS-435 Fence – 1,818 feet.
- Escape Ramp – One, place this ramp 660 feet from the bridge along the bend in the fence where the creek bisects the highway.
- Gate – One, place gate near the west side of the bridge to allow for mowing operations.

Expected reduction of WVCs to be approximately 22 percent.

6.6.2.4 MO-45 TRAFFIC CIRCLE INTERSECTION WITH WEST BRINK MEYER ROAD/COUNTY ROAD – MP 6.68

The wildlife crashes on MO-45 are in an area of heavy development, near the intersection of County Road-Brink Meyer Road. The traffic circle at this intersection helps to slow traffic and may help to reduce future WVCs. However, westbound traffic enters this area from a higher elevation, and the western line-of-sight is blocked by a hill. All three crashes in this section were recorded on the westbound lanes; limited line-of-sight visibility may be contributing to WVCs occurring in the westbound lanes at this location.

Figure 6-46: Traffic Circle Intersection with West Brink Meyer Road/County Road at MP 6.68.



Short Term Action

At MO-45 N MP 6.5, place a solar powered set of flashing lights with a deer-crossing sign on the westbound lane, just to the east of NW Brightwell Road.

Figure 6-47: An example of a wildlife sign with solar powered LED lights in Wyoming.



Source: P. Cramer.

Expected reduction of WVCs to be approximately 5 percent.



6.6.2.5 76TH STREET BRIDGE AND NAYLOR CREEK CULVERT – MP 52.04

Four previously reported WVCs occurred in this area of IS-435, indicating that wildlife are attempting to cross the highway in this location. The existing culvert under IS-435 could be replaced with a larger culvert, to accommodate both additional water flow and terrestrial wildlife movement. The culvert is currently perched, and there is a pool of water at the entrance. To place terrestrial pathways along a new culvert, the culvert would need to be higher in the berm to allow terrestrial movement along the current dry areas, which would negate its use for aquatic organism passage. A more detailed look at this culvert and its replacement would need to occur in order to recommend a more precise prescription. This is recommended to occur in the future, prior to MoDOT's scheduled replacement of the culvert.

6.6.2.6 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-28** and depicted in **Figure 6-48** and **Figure 6-49**.

Table 6-28: Parma Woods Shooting Range Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
IS-435 Bridges Over River Road – A3330 & A3463 	55.04, S 0.53	Maintain soil pathways under overpass. Clear garbage and debris from side of River Road, and within ROW along River Road.	Place 10,089 feet fence. Fence should extend northeast by about 5,060 feet and northwest about 4,980 feet. Add median fence extending about 49 feet. Add four escape ramps and two gates.	None
IS-435 Box Culvert 	54.23	None	None	Replace box culvert with either two larger box culverts and an open median, or with two bridges.
SH-45 Bridge Over IS-435 – A3318	30.01	None	Place 1,818 feet of fence south from the west side abutment of the MO-45 south bridge (for eastbound traffic).	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
			Add one escape ramp and one gate.	
SH-45 Traffic Circle Intersection with West Brink Meyer Road/County Road 	6.68	Place a wildlife sign with solar powered flashing lights on MO-45, N MP 6.49	None	None
76th Street Bridge and Naylor Creek Culvert – A3329 	52.04	None	None	Replace existing culvert to allow for aquatic organism and terrestrial wildlife passage.

Figure 6-48: Parma Woods Shooting Range Mitigation Recommendations, MO-45 and IS-435.

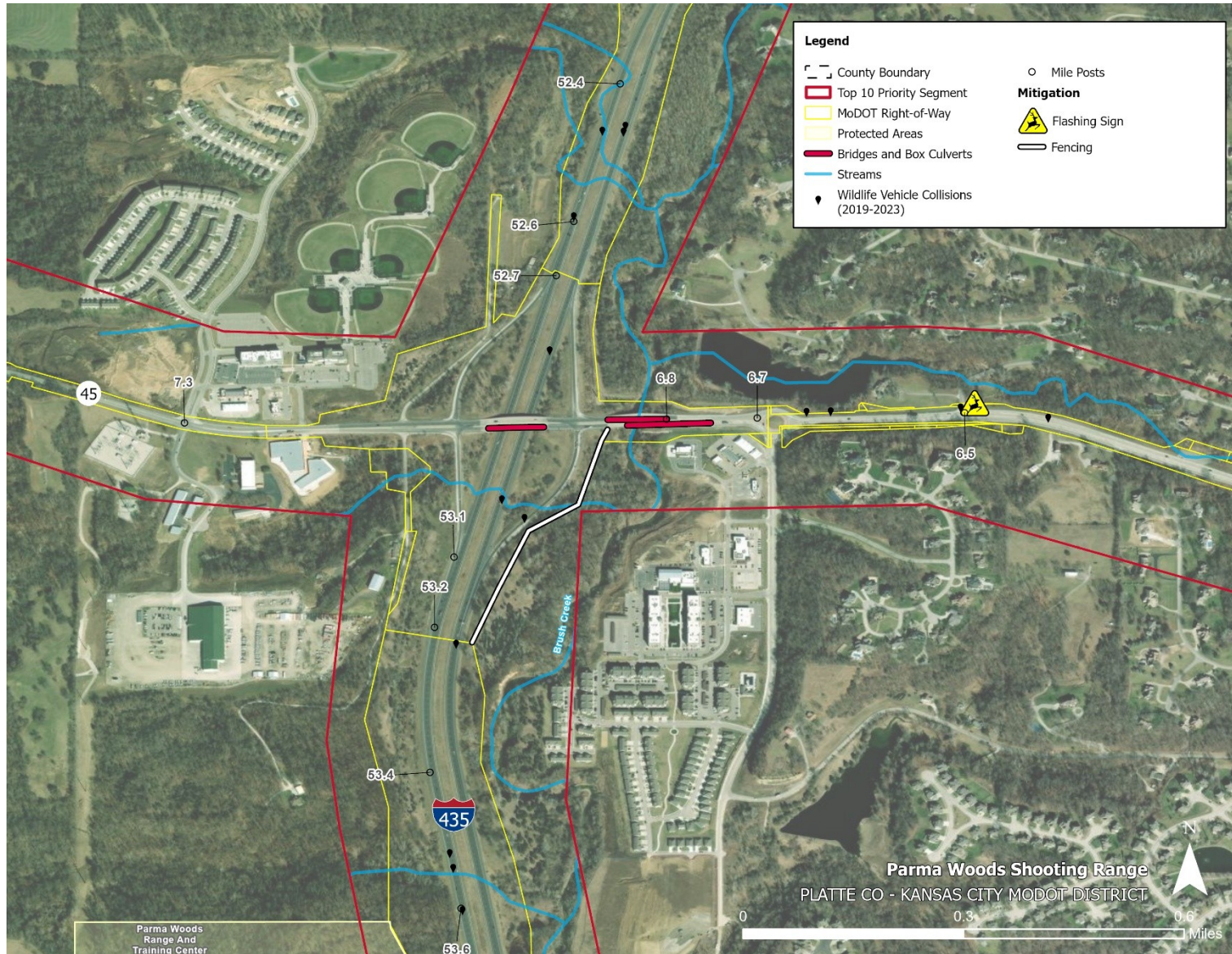
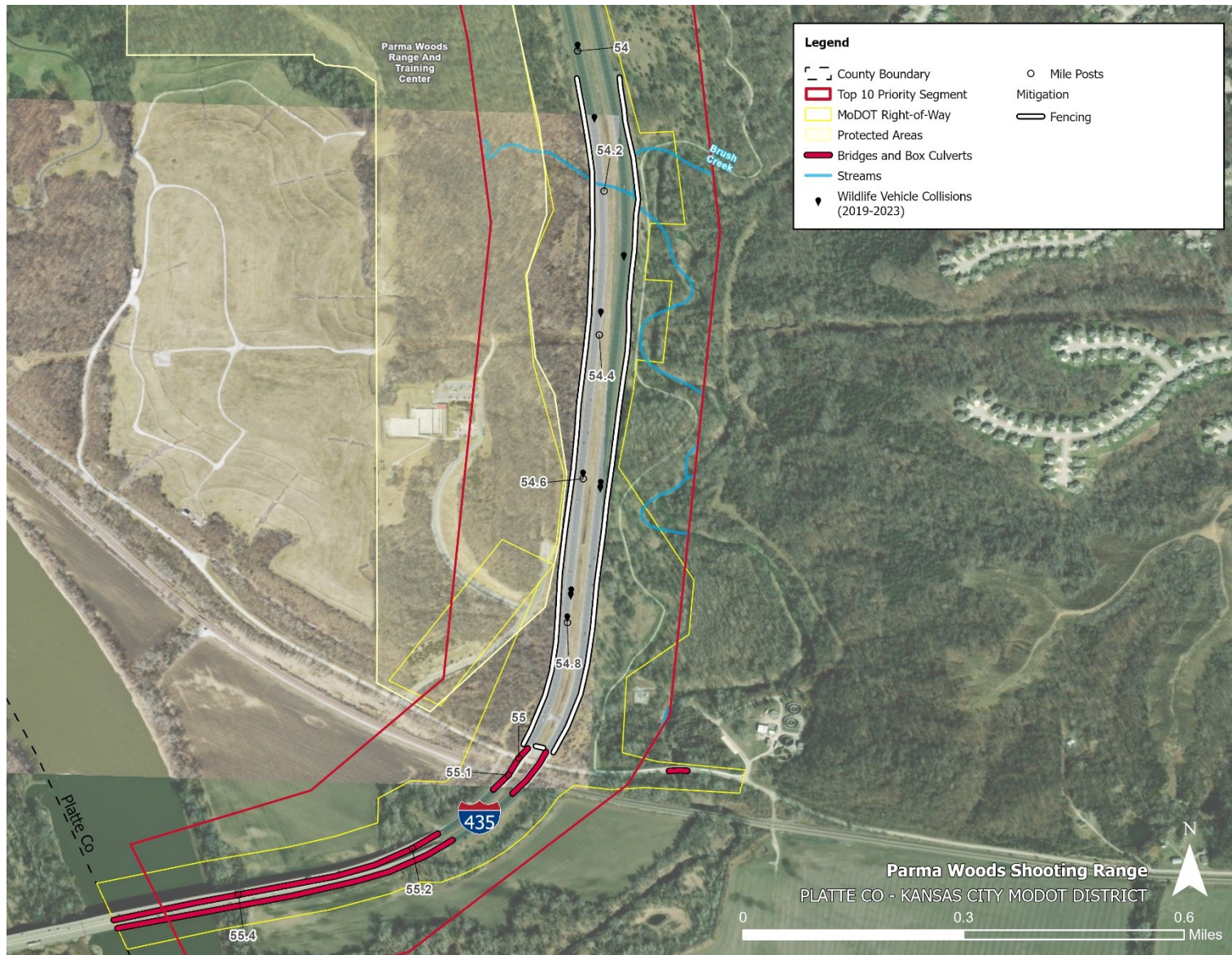


Figure 6-49: Parma Woods Shooting Range Mitigation Recommendations, IS-435.





6.6.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 12.87, with a payback period of 3.89 years.

Table 6-29: Parma Woods Shooting Range Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	11,907	\$30 per linear foot	\$357,210
Gates	3	\$1,500	\$4,500
Escape Ramps	5	\$22,000	\$110,000
Materials Total	--	--	\$471,710
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$521,710

Table 6-30: Parma Woods Shooting Range WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	55	\$15,956	\$877,580	--
Minor Injury	3	\$204,700	\$614,100	--
Serious / Disabling Injury	1	\$787,600	\$787,600	--
Cost For 5 Years	--	--	--	\$2,279,280
Average Cost Per Year	--	--	--	\$455,856

Table 6-31: Parma Woods Shooting Range Benefit Cost Ratio Calculations.

Benefits Formula		(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years	
Benefits Values	(455,856 + (2,000 x 11.8)) x 0.28 x 50		
Costs Formula		Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)	
Costs Values	471,710 + (1,000 x 50)		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$6,712,384	\$521,710	12.87	3.89 years

6.7 Fox River and Buck Run

6.7.1 Project Overview

Fox River and Buck Run lie within the Mississippi River floodplain; a geographically unique place in Missouri for protecting wildlife and water connectivity (**Figure 6-50** and **Figure 6-51**). This fertile soil area largely consists of privately owned agricultural lands with little chance of development due to intermittent flooding.

The Buck Run area has three large culverts that are 200 to 300 feet long. The two 200-foot culverts could be suitable for white-tailed deer movement. Vegetation clearing at the entrances of all culverts could help deer and other wildlife find and use these culverts. The most likely short-term remedies for this Top 10 segment are those that clear ROW vegetation to help drivers' line of sight at approaches to the areas near the culverts and past deer-vehicle crashes, and a static warning sign with LED flashing lights.

The Buck Run area, the more southern portion of the Top 10 segment, is bordered by parcels enrolled in the Wetlands Reserve Program and thus under conservation easement, and by the Buck and Doe Run Conservation Area to the east. A summary of the Top 10 segment and its criteria are provided in **Table 6-32**. The most southern culvert in the Buck Run area, at 115th Street and U.S. 61, could be retrofitted with fence to guide white-tailed deer and other wildlife to the culvert. The culvert was largely dry with some wet spots during the site investigation and is under 200 feet, making it a potential place for white-tail deer to cross beneath the road. A second retrofit to this triple box culvert could be adding a skylight hole in the ceilings of the three cells of the culvert where it intersects with the median. This would encourage deer and other wildlife use. The dispersed nature of the past wildlife crashes, the private land ownership, and water-laden landscape make the situation difficult for placing new wildlife crossing structures.

To the north, the pair of MO-27 bridges over the Fox River are high and long and can be retrofitted with fences to channel white-tailed deer and other wildlife beneath the highway in the one-mile area of the Fox River area. Existing box culverts in both areas could be improved for wildlife and water movement with yearly vegetative clearing by MoDOT Maintenance in the spring.



Table 6-32: Fox River and Buck Run Description and Criteria.

Name: Fox River and Buck Run	
MoDOT District: Northeast	
County: Clark and Lewis	
Road and Mile Posts: MO-27 MP 0 to 1 and U.S. 61 MP 374 – 377	
Total Miles: 4	
STIP Description: Pavement improvement on southbound lanes from Fox River to 1.2 miles north of Rte. B in Lewis County near Canton (seven disconnected sections) and from Iowa State line to Rte. 27 interchange. Pavement improvements from the Iowa State line to 0.5 mile north of Rte. B in Lewis County near LaGrange (nine disconnected sections). Project includes southbound and northbound lanes on Rte. 27 from the Iowa State line to the Rte. 61 interchange.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	19
Wildlife Crashes per Mile per Year	0.95
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	47.5%
<i>Ecological</i>	
AADT	4,270 – 13,836
Occupied Habitat	Up to 6 priority species known to occur.
Predicted Suitable Habitat	Up to 19 priority species including: Kirtland's snake, black-tailed jackrabbit, eastern tiger salamander, American badger, Franklin's ground squirrel, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, and alligator snapping turtle.
MDC CCS Management Tiers	Frost Island Sand Prairies and Wetlands Landscape COA – Tier 2 Buck Run Creek 2005 Aquatic COAs in Priority Watersheds – Tier 3 Buck Run Creek Priority Watershed – Tier 3 Mississippi River COA Stream Reach Watersheds – Tier 3
Named Streams	Fox River, Doe Run
Bridges and Culverts	2 bridges, 1 box culvert
<i>Feasibility</i>	
Land Use	22.6 – 30.4% Developed
Protected Areas	Wetland Reserve Program, Buck and Doe Run Conservation Area (east side of highway)
<i>Qualitative Review</i>	
Constructability	1.67 – 2.67
Land Use	2.67 – 3
STIP Rating	1

Figure 6-50: Fox River Overview Map.

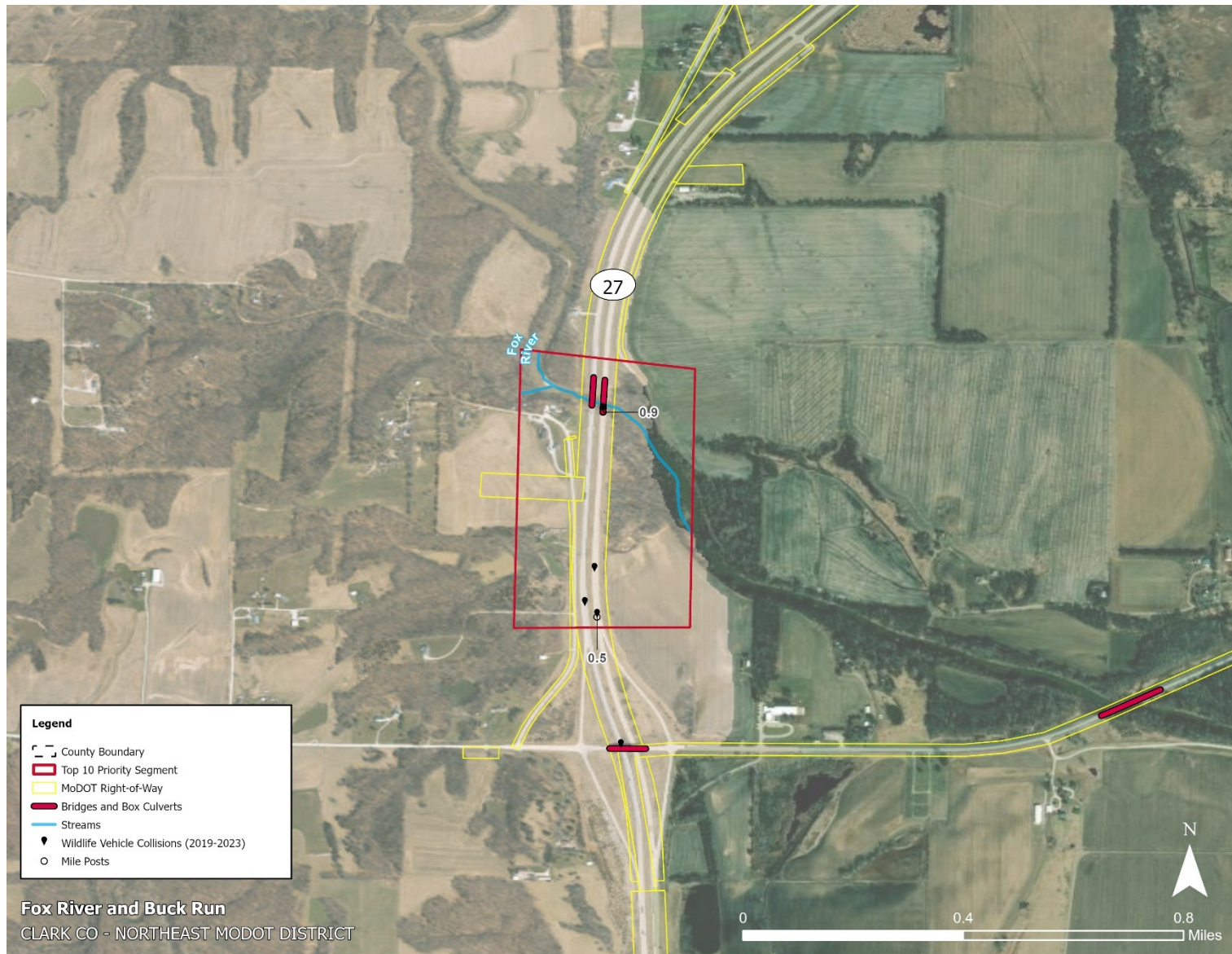
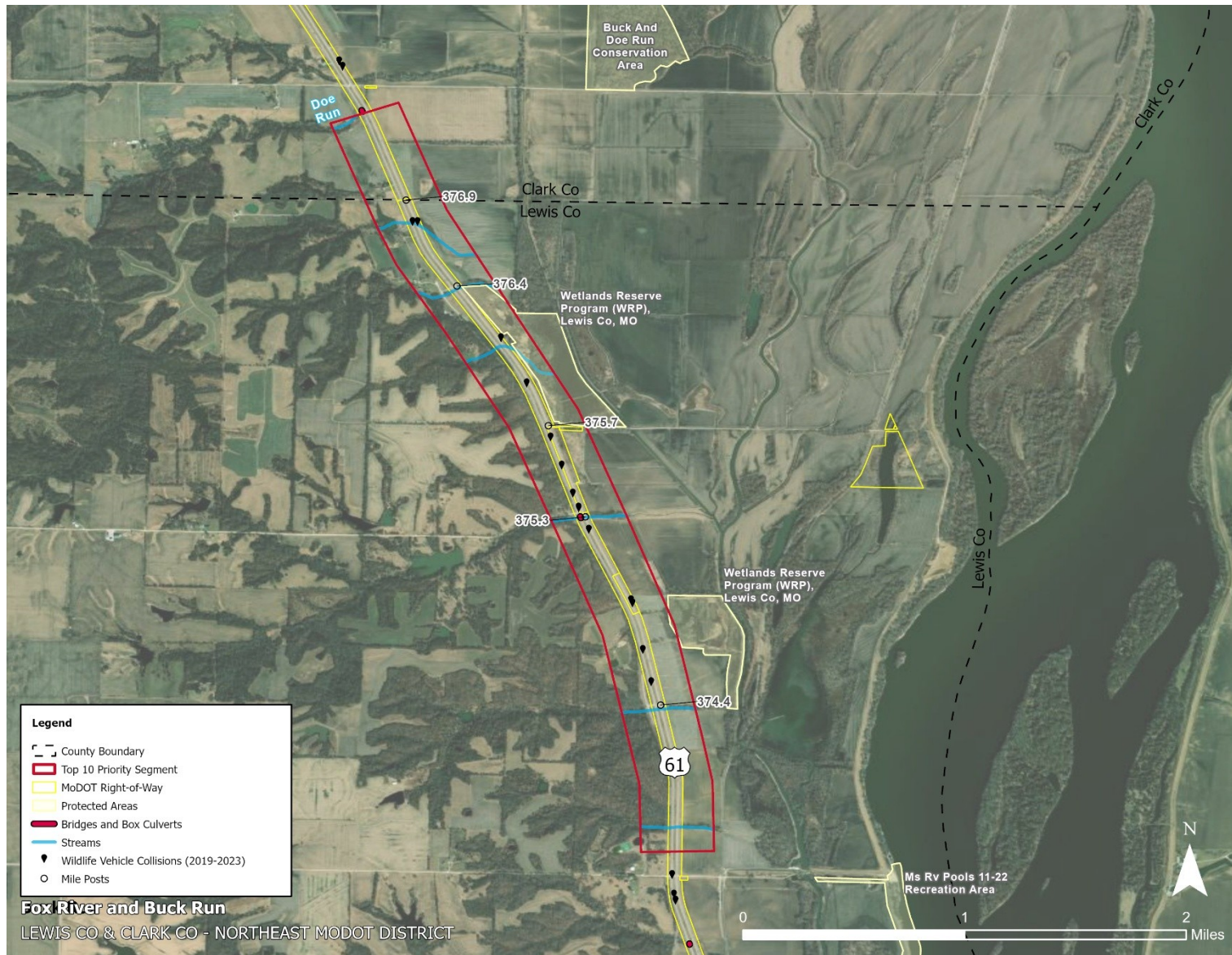


Figure 6-51: Buck Run Overview Map.



6.7.2 Recommendations

The recommended mitigation strategies for this Top 10 segment are to add fences to the existing bridge at Fox River, and erect fence off of the farthest south triple box culvert near 115th Street. There are other short-term recommendations to trim back ROW vegetation and vegetation at the entrances to culverts, and to place static signs with flashing LED lights warning drivers of their approach to areas where hilly terrain prevents a line of sight, increasing the risk of WVCs.

6.7.2.1 MO-27 FOX RIVER DOUBLE BOX CULVERT – MP 0.51

This box culvert has two 4 feet high by 10 feet wide cells, which would be less than 5 feet wide per cell. The culvert is located under CR 307 and MO-27 and is long, with a length of approximately 300 feet. The long, dark conditions of the culvert is only acceptable for use by amphibians and small to medium-sized mammals **Figure 6-52**).

Short Term Actions

The vegetation at the entrance should be trimmed and cut back annually in June to allow animals to find and possibly use the culvert. Regular vegetative maintenance would also improve water flow, helping to prevent flooding and making the transportation network more resilient.

Figure 6-52: Fox River Double Box Culvert at MP 0.51.



6.7.2.2 MO-27 FOX RIVER BRIDGES – MP 0.9

This pair of bridges over the Fox River are approximately 10 feet above the terrestrial pathways below and approximately 270 feet long (**Figure 6-53**). White-tailed deer tracks were present during the field investigation. It is recommended that wildlife exclusion fencing be added to both sides of MO-27 southward for approximately 0.14 miles from the bridge abutment and for one-third of a mile north, on both sides of the highway, to just past the Fox River bend where it comes close to the highway. The upcoming STIP project for southbound MO-27 lanes could include these recommended fences, gates, and escape ramps.

Retrofit Infrastructure

- Total Fence – 5,106 feet
 - Northeast Fence (from bridge) – 1,878 feet
 - Northwest Fence – 1,896 feet

- Southwest Fence from bridge – 642 feet
- Southeast Fence – 608 feet
- North Median Fence – 41 feet
 - South Median Fence – 41 feet
- Escape Ramps – Two on north fences, one on each side
- Gates – Four to allow for maintenance access

Expected reduction of WVCs to be approximately 50 percent.

Figure 6-53: Fox River Bridges at MP 0.9.



6.7.2.3 MO-27 BUCK RUN U.S. 61 SCHLOTTER LAKE CULVERT – MP 376.8

This double box culvert accommodates water from a canal/ditch that is dammed on the Schlotter property to form a small lake on the west of MO-27. Two deer-vehicle collisions were recorded right over the culvert. The culvert is 6 feet tall and 175 feet long, and the two boxes of the culvert are 20 feet wide in total. White-tailed deer may use this culvert to move beneath the highway. Traffic coming from the north have poor line of sight to avoid deer at this location due to the hilly terrain. The most economic action is to warn drivers and make the culvert more accessible to wildlife.

Short Term Actions

Vegetation should be removed from both entrances to the culvert, and stumps removed. The cleared area should be expanded outward from the culvert entrances into the ROW, to allow wildlife to find the culvert for possible use. Medium and small-sized mammals and amphibians could use the culvert.

A static deer warning sign with flashing LED lights that are solar powered should be placed near the intersection of N 1st street for the southbound drivers to be warned of the potential for wildlife on the road on the south side of the hill at the culvert.

Figure 6-54: Buck Run U.S. 61 Schlottter Lake Culvert at MP 376.8.



6.7.2.4 U.S. 61 BUCK RUN AND OLD HIGHWAY 61 DOUBLE BOX CULVERT – MP 376.4

This double-wide box culvert is 5 feet high, 8 feet wide, and approximately 185 feet long (**Figure 6-55**). White-tailed deer may use this structure. If the brush was cut back at both entrances out to the ROW fence, deer and smaller animals such as medium-sized mammals could find and possibly use it to safely cross beneath U.S. 61. The culvert was dry at the time of the field investigation, which would provide ideal conditions for all terrestrial animals. The natural floor is also ideal for amphibian movement.

Short Term Actions

Herbaceous and brushy vegetation should be cleared from the entrances back to the ROW fence line to allow wildlife to find and access the culvert.

No recorded WVCs have occurred within 1,000 feet of the culvert within the past five years; therefore, a retrofit solution to encourage usage by white-tailed deer is not currently proposed for this culvert.

Figure 6-55: Buck Run U.S. 61 and Old Highway 61 Double Box Culvert - MP 376.4.



6.7.2.5 U.S. 61 BUCK RUN 115TH ST TRIPLE BOX CULVERT – MP 375.3

This 10 feet high, triple box culvert is just south of the intersection with 115th Street. The width of each cell of the culvert is approximately 10 to 14 feet, and the culvert is approximately 175 to 200 feet long. This length is within the acceptable range for use by white-tailed deer.

Short Term Actions

Brushy vegetation should be cleared at the entrances of the culvert back to the ROW fence line to allow wildlife to find and access the culvert (**Figure 6-56**). It is assumed deer and other wildlife use 115th Street to move eastward and cross the highway here, as there were two reported deer-vehicle collisions reported at this exact location. Clearing all vegetative growth in the ROW on the west side of the highway would allow drivers approaching the area from the north to have a better line of sight to possible deer in the highway at the 115th Street intersection. These actions have an anticipated 10 percent reduction in WVCs.

Figure 6-56: Buck Run U.S. 61 115th St. Triple Box Culvert – MP 375.3



Retrofit Infrastructure

Fences can be added north and south along U.S. 61 from the corners of the culvert to guide deer and other wildlife to the culvert. This is expected to reduce WVCs by 30 percent.

- Total Fence – 3,260 feet
 - Northeast Fence – 756 feet
 - Northwest Fence – 761 feet
 - Southwest Fence – 875 feet
 - Southeast Fence – 868 feet
- Double Cattle Guard – One at 115th Street

Infrastructure Solutions

It is recommended that an opening in the roof of the culvert be cut where it intersects the U.S. 61 median (**Figure 6-57**). This will allow more light into the culvert and help encourage deer and other wildlife use. The opening should be approximately 20 feet wide by 20 feet long (depending on the total length of the three cells – they should all have a sky light) and be covered with a grate for human and wildlife safety. This mitigation is expected to reduce WVCs by 35 percent.

Figure 6-57: Single Cell of Buck Run U.S. 61 115th St. Triple Box Culvert – MP 375.3. Photograph is lit by camera flash.



6.7.2.6 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-33** and depicted in **Figure 6-58**, **Figure 6-59**, and **Figure 6-60**.

Table 6-33: Fox River and Buck Run Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Fox River Double Box Culvert MO-27 	MO-27 N MP 0.51	Trim down vegetation and trim regularly	None	None
Fox River Bridges – A6789 & A4213 	MO-27 N MP 0.9	None	Place fence lines off of each corner of the bridge abutment. South fence extends about 642 feet; north fence extends about 1,880 feet. Add four gates and escape ramps.	None
U.S. 61 Schlotter Lake Culvert	U.S. 61 S MP 376.8	MoDOT Maintenance needs to bush mow the young trees and bushes at both entrances to this culvert, and outward from there to the ROW. Add a static deer warning sign with flashing LED lights for southbound drivers.	None	None

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
				
U.S. 61 and Old Highway 61 Double Box Culvert 	U.S. 61 SMP 376.4	Clear trees and brushy vegetation from both entrances and out to the ROW fence.	None	None
115th St Triple Box Culvert – A5959 	U.S. 61 S MP 375.3	Clear trees and brushy vegetation from both entrances and out to the ROW fence. Clear all vegetation in the ROW of the west side of the highway.	Place fence about 750 feet to the north and about 875 feet to the south. Add one double cattle guard.	Cut a skylight hole in the ceiling of the box culvert in the median between opposing lanes.

Figure 6-58: Fox River Mitigation Recommendations.

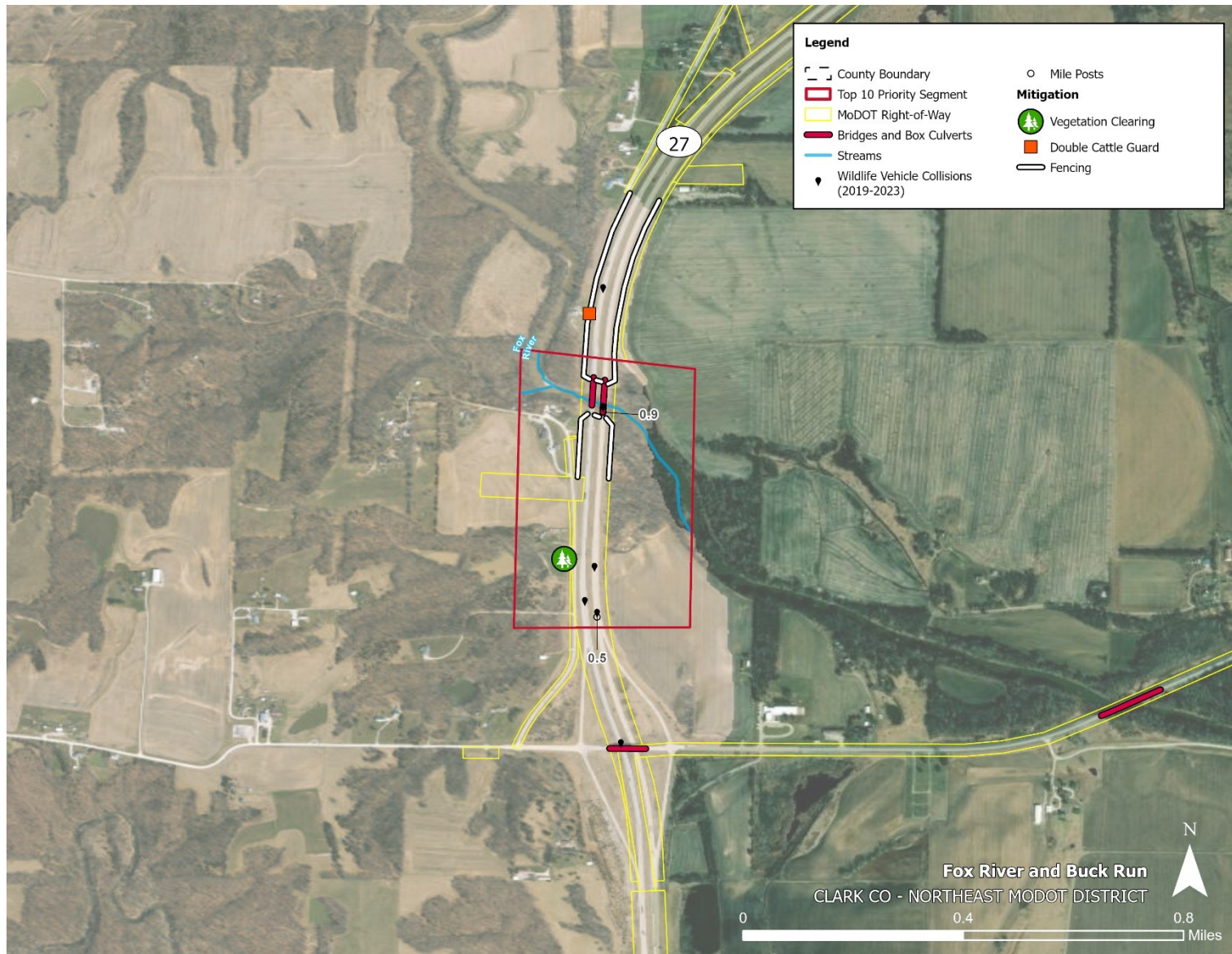


Figure 6-59: Buck Run Mitigation Measure Recommendations, North.

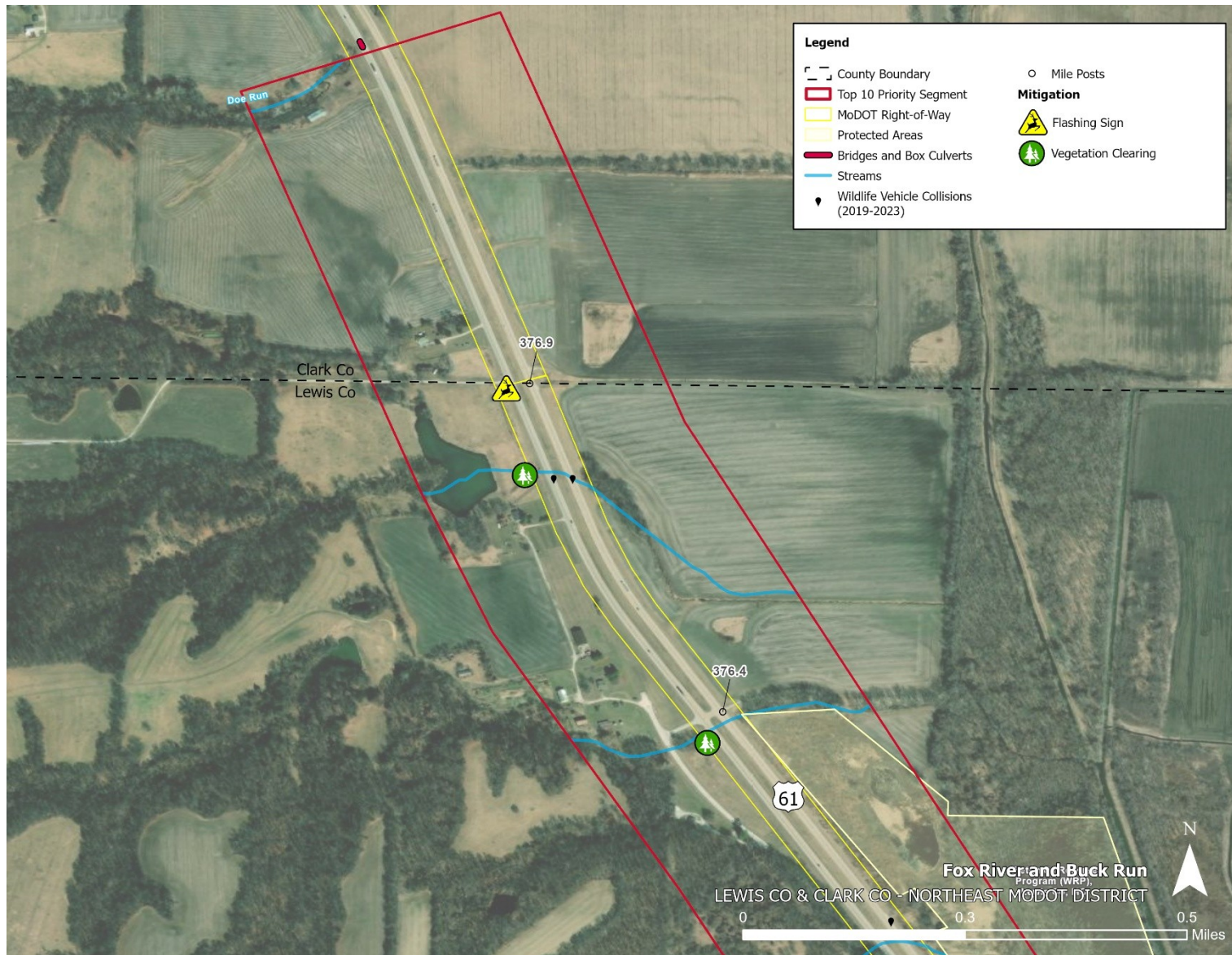


Figure 6-60: Buck Run Mitigation Measure Recommendations, South.





6.7.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 0.84, with a payback period of 59.7 years.

Table 6-34: Fox River and Buck Run Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total
Fence	8,366	\$30 per linear foot	\$250,980
Gates	4	\$1,500	\$6,000
Escape Ramps	2	\$22,000	\$44,000
Road Double Cattle Guards 32 foot	1	\$78,000	\$78,000
Materials Total	--	--	\$378,980
Maintenance	50 years	\$1,000 per year	\$50,000
Grand Total	--	--	\$428,980

Table 6-35: Fox River and Buck Run WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	4	\$15,956	\$63,824	--
Minor Injury	0	\$204,700	0	--
Serious or Disabling Injury	0	\$787,600	0	--
Total Costs	--	--	--	\$63,824
Total Costs per Year	--	--	--	\$12,765

Table 6-36: Fox River and Buck Run Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	$(12,765 + (2,000 \times 0.8)) \times 0.50 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	$378,980 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$359,120	\$428,980	0.84	59.7 years



6.8 Long Branch State Park

6.8.1 Project Overview

This area is along U.S. 36 to the west of Macon, Missouri and just west of Long Branch State Park. Although the lands next to the highway in this Top 10 segment are privately owned, the existing bridge at the Middle Fork of Little Chariton River is long and high and is already being used by wildlife to traverse the riverine habitat. With certain retrofits, the existing bridge can help reduce WVCs. The dominant land use of areas near the highway is agriculture, while land use within the remainder of the Top 10 segment primarily consists of forested riparian zones and waterbodies with minimal likelihood of being developed. There is a conservation easement in the Wetlands Reserve Program just northeast of the highway. A small piece of land adjacent to the highway on the north end was owned by MoDOT as a wetland reserve but has been sold to private ownership.

The field investigation noted many white-tailed deer and other wildlife tracks beneath the U.S. 36 bridges. A little brown bat (*Myotis lucifugus*) was found roosting beneath the U.S. 36 Middle Fork of Little Chariton River bridge. There is a bridge to the west end of this Top 10 segment over a ravine, but there is no partner bridge for the opposite lanes of traffic, thus it is not a viable option to channel wildlife to move beneath the highway. An estimated total of 1.28 miles of fence is recommended to be added to the bridges over the Middle Fork of the Little Chariton River on both sides of the highway. The addition of fencing is expected to decrease reported WVCs by approximately 80 percent.

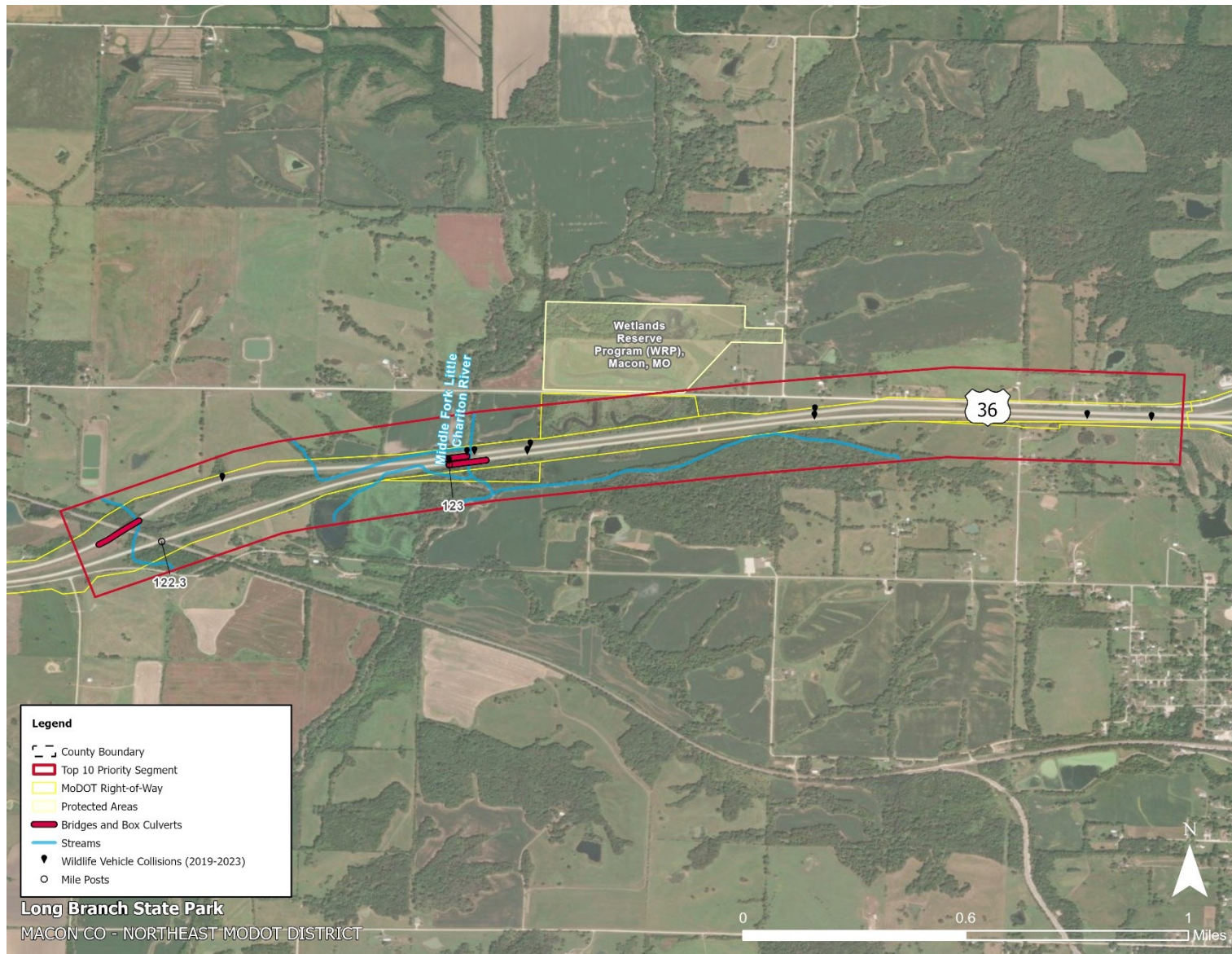


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Table 6-37: Long Branch State Park Description and Criteria.

Name: Long Branch State Park	
MoDOT District: Northeast	
County: Macon	
Road and Mile Posts: U.S.36 MP 122 – 124.4	
Total Miles: 2.5	
STIP Description: Pavement resurfacing and bridge joint and deck repair from 0.5 mile west of Rte. C to 0.1 mile east of Kellogg Avenue near Macon and on westbound from Kellogg Avenue to 1.7 miles west of Rte. O. Project involves bridges A3820 and A2041. Funding allocated for 2026.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	12
Wildlife Crashes per Mile per Year	1
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	40%
<i>Ecological</i>	
AADT	10,446
Occupied Habitat	Up to 5 priority species known to occur.
Predicted Suitable Habitat	Up to 17 priority species including black-tailed jack rabbit, eastern tiger salamander, American badger, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle.
MDC CCS Management Tiers	Thomas Hill – Tier 3 Long Branch Watershed – Tier 4
Named Streams	Middle Fork Little Chariton River
Bridges and Culverts	3 bridges
<i>Feasibility</i>	
Land Use	22 – 26% Developed
Protected Areas	Wetland Reserve Program, Nearby Long Branch State Park
<i>Qualitative Review</i>	
Constructability	2
Land Use	2.33
STIP Rating	2

Figure 6-61: Long Branch State Park Overview Map.



6.8.2 Recommendations

The main recommendation for mitigating WVCs is to place wildlife exclusion fence on the pair of U.S. 36 Middle Fork of the Little Chariton River bridge abutments. The fences would total 1.28 miles of highway and would include fences on both sides of the highway. The fences would also be installed with four gates to allow access for mowing, and 10 escape ramps. The ramps should be placed in concert with MDC biologists/ecologists.

A short-term action recommended at these bridges is to place a guard rail along the north side of the westbound traffic bridge to keep wildlife from jumping onto the highway. The vegetation beneath the bridges has become overgrown, and clearing the scrub/shrub habitat would help wildlife find the bridge area and move beneath. The area to the west, where the long, high bridge crosses a ravine, also needs vegetation maintenance. Trimming back the vegetation in the north ROW would improve line of sight for westbound drivers approaching the curve, where multiple wildlife crashes have been recorded. The lack of a bridge over the area for eastbound traffic makes this area difficult for funneling wildlife beneath the road.

6.8.2.1 STEEP RAVINE AND RAIL LINE BRIDGE – MP 122.3

This location has the odd distinction of a westbound traffic bridge over a ravine (**Figure 6-62**), with no corresponding paired bridge for the eastbound traffic because it is perched on the edge of the ravine. Wildlife could easily traverse under U.S. 36 below the westbound bridge but could not access the southern side of U.S. 36 without going over the highway at-grade. No fencing is recommended, therefore, due to U.S. 36 eastbound lane being at-grade with no viable option to funnel wildlife over or under the highway.

Figure 6-62: Steep Ravine and Rail Line Bridge at MP 122.3.



Short Term Actions

The westbound lanes are on a curve, making the line of sight on the approach to the bridge area limited (**Figure 6-63**). Trees and shrubs in the median should be cut back to improve the line of sight to the west. Extend the tree and shrub removal eastward 1,400 feet from the open area near

the bridge. This should increase the westbound drivers' line of sight and improve avoidance of WVCs.

Figure 6-63: Poor line of sight around curve due to vegetation. Clearing recommended south of highway.



6.8.2.2 U.S. 36 MIDDLE FORK OF THE LITTLE CHARITON RIVER BRIDGES – MP 123

The pair of bridges at this river are perfect de facto wildlife crossing bridges, and there was ample evidence of white-tailed deer use beneath them (**Figure 6-64**). The two bridges are not perfectly aligned, with the north bridge for the westbound traffic much shorter than the south bridge for the eastbound traffic.

Figure 6-64: Middle Fork of the Little Chariton River Bridges at MP 123.





Short Term Actions

Place a guard rail along the north side of the westbound traffic bridge to keep wildlife from jumping onto the highway, to hopefully guide them back to the east to use the bridge. Add soil on the rip rap pathway under the north westbound bridge to facilitate wildlife movement. Lastly, cut brush near the entrances below the bridges to allow better access for wildlife passage.

Retrofit Infrastructure

Place wildlife exclusion fences off the corners of each bridge.

- Total Fence –13,533 feet
 - Westbound Northwest Fence – 2,099 feet, place fence to the west of the curve along the ROW fence.
 - Westbound Northeast Fence – 4,602 feet, side place on bridge abutment and run along ROW fence to Hickory Street.
 - Eastbound Southwest Fence – 2,052 feet, just west of the pond on the south side of the highway.
 - Eastbound Southeast Fence – 4,586 feet.
 - West Median Fence – 112 feet.
 - East Median Fence – 82 feet.
- Escape Ramps - Ten
- Gates – Four gates for access to mow grass and control vegetation.

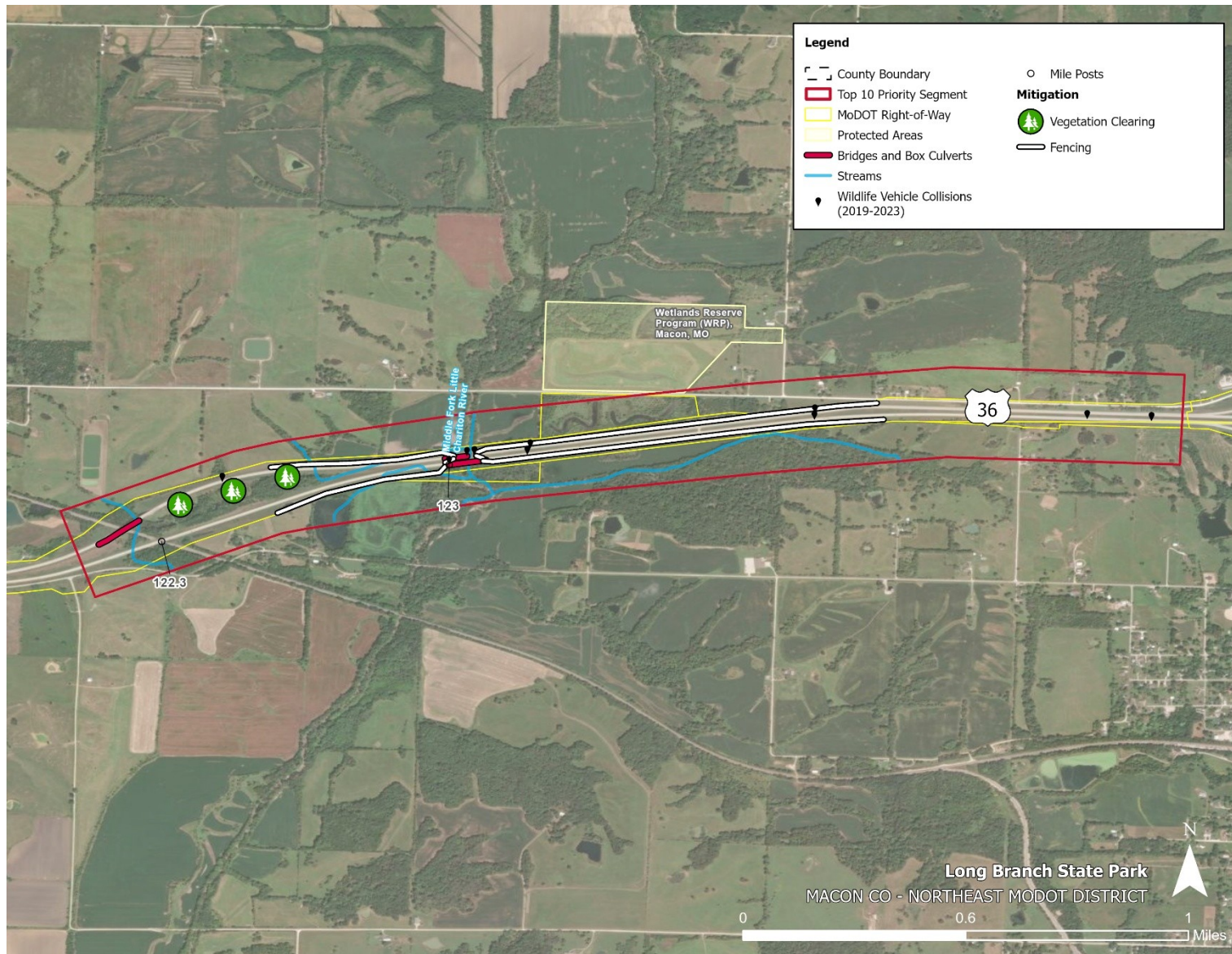
6.8.2.3 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-38** and depicted in **Figure 6-65**.

Table 6-38: Long Branch State Park Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Steep Ravine and Rail Line Bridge – A6094 	122.3	Trees and bushes in the median (to the north side) should be cut back to improve the line of sight to the west.	None	None
U.S. 36 Middle Fork Little Chariton River Bridges - L0569 & A6095 	69.6	Install guardrail along the north side of the westbound bridge. Vegetation management – cut back brush beneath bridges, and place soil over rip rap rocks.	Install fences: North fence about 2,099 feet; southwest fence about 2,052 feet; northeast fence about 4,602 feet; southeast fence about 4,586 feet. Add four gates and 10 escape ramps.	None

Figure 6-65: Long Branch State Park Mitigation Recommendations.





6.8.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 2.53, with a payback period of 19.8 years.

Table 6-39: Long Branch State Park Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	13,533	\$30 per linear foot	\$405,990
Gates	4	\$1,500	\$6,000
Escape Ramps	10	\$22,000	\$220,000
Materials Total	--	--	\$631,990
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$681,990

Table 6-40: Long Branch State Park WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	12	\$15,956	\$191,472	--
Minor Injury	0	\$204,700	0	--
Serious / Disabling Injury	0	\$787,600	0	--
Cost For 5 Years	--	--	--	\$191,472
Average Cost Per Year	--	--	--	\$38,294

Table 6-41: Long Branch State Park Benefit Cost Ratio Calculations.

Benefits Formula		<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>	
Benefits Values		$(38,294 + (2,000 \times 2.4)) \times 0.80 \times 50$	
Costs Formula		<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>	
Costs Values		$631,990 + (1,000 \times 50)$	
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$1,723,776	\$681,990	2.53	19.8 years



6.9 Maramec Spring State Park

6.9.1 Project Overview

This Top 10 segment lies completely within Maramec Spring State Park. The park is partially co-owned by the James Foundation, which donated the land for the park. The lands to the north side of MO-8 are managed for agriculture and contain hay fields. Deer were observed in the field during the field investigation. The remainder of the land within the Top 10 segment consists of forests with interspersed rivers and creeks. Woody debris left behind on the MO-8 bridge by previous major flooding events on the Meramec River indicated the floodwaters can reach up to 15 feet above normal river levels. The State Park is a dynamic landscape used by recreationists to camp, canoe, swim, float, and fish the river, hike the uplands, and explore. The mitigation recommendations discussed below were made to provide these recreationists with access to the river areas while guiding white-tailed deer to cross the road beneath the bridges.

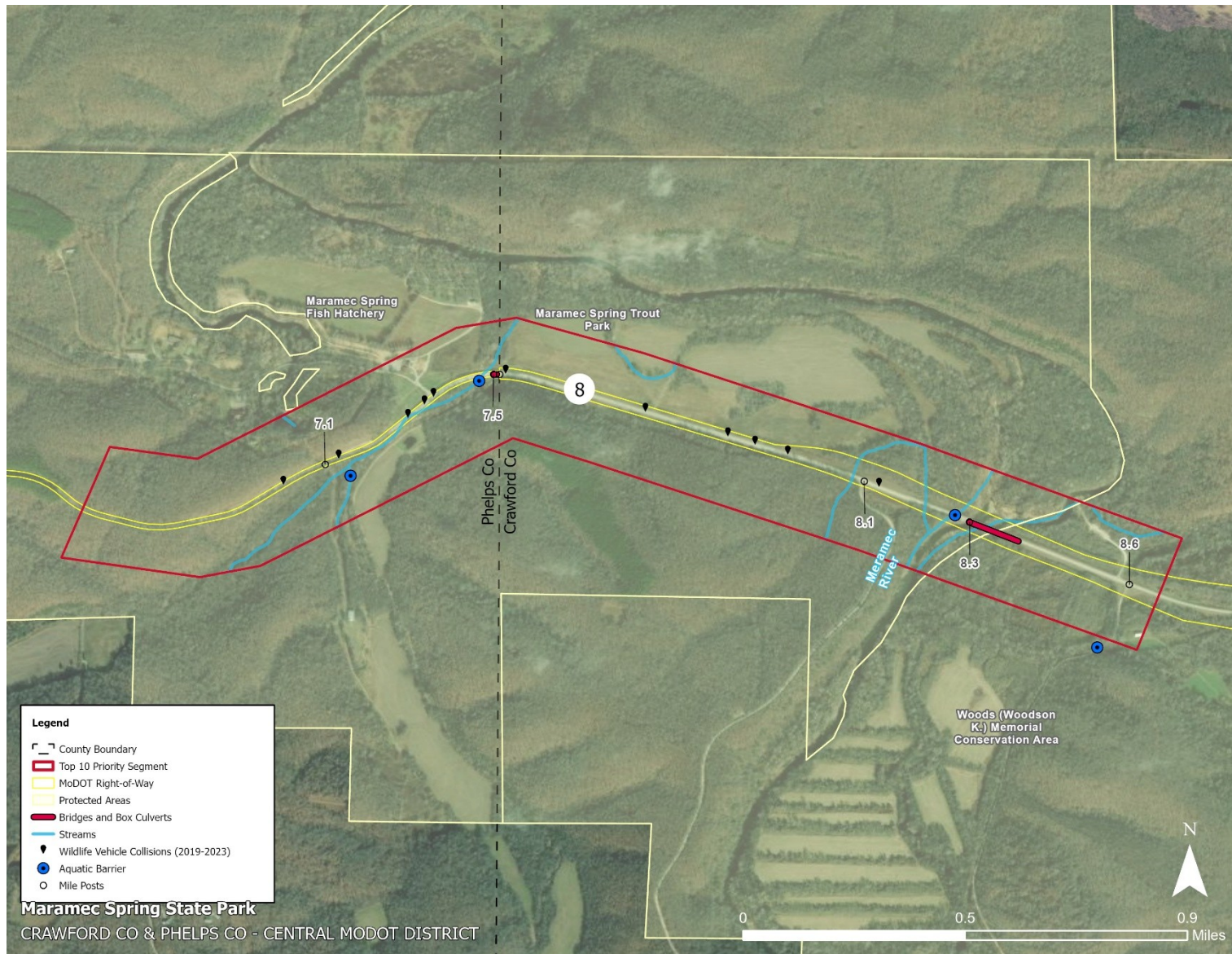


Missouri Statewide Wildlife Vehicle Collision Study Alternatives Analysis and Recommended Improvements

Table 6-42: Maramec Spring State Park Description and Criteria

Name: Maramec State Park	
MoDOT District: Central	
County: Crawford	
Road and Mile Posts: MO-8 MP 6- 8	
Total Miles: 2	
STIP Description: None	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	11
Wildlife Crashes per Mile per Year	1.1
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	73%
<i>Ecological</i>	
AADT	1,350
Occupied Habitat	Up to 3 priority species known to occur.
Predicted Suitable Habitat	Up to 19 priority species including Kirtland's snake, black-tailed jack rabbit, eastern tiger salamander, American badger, Franklin's ground squirrel, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle.
MDC CCS Management Tiers	Meramec River – Tier 2 Dry Fork Upper Meramec – Tier 3 Meramec River Hills – Tier 3 Middle Meramec River – Tier 3 Woodson K Woods – Tier 3
Named Streams	Meramec River
Bridges and Culverts	2 bridges
<i>Feasibility</i>	
Land Use	22 – 26% Developed
Protected Areas	Maramec Spring State Park
<i>Qualitative Review</i>	
Constructability	3
Land Use	3
STIP Rating	0

Figure 6-66: Maramec Spring State Park Overview Map.



6.9.2 Recommendations

The most straight forward mitigation recommendation is to add wildlife exclusion fence to the west side of the Meramec River bridge, along MO-8, for approximately 0.19 mile. Gates would be installed in the fence at the bridge abutment to allow recreationists to access the river and road. An additional short-term action for this bridged area would be to place or clear a path in the rip rap and concrete placed around the bridge abutment to assist wildlife and human movements beneath the bridge.

A more difficult situation is present near the park entrance, where more deer were involved in WVCs than near the Meramec River. The high human use of the area, and potentially unwelcome addition of a fence in that area may become problematic. The most effective recommendation for reducing WVCs in this area is to fence the stretch of road from the Meramec River bridge westward past the park entrance the cliffs on the north side of the road. This stretch of 1.2 miles of fence may not be acceptable to park officials. If so, a reduced fence length of 0.32 miles from the bridge of the unnamed tributary near the park entrance westward to the cliffs would be the secondary fencing recommendation.

While these recommendations would help to reduce WVCs in their specific areas, there is a 0.7 mile (3,700 feet) stretch of the road where four past WVCs were reported. This portion of the Top 10 segment, from MP 7.5 to 8.1, is bordered by hay fields that attract white-tailed deer. Fencing is recommended in this area to prevent white-tailed deer collisions. The road in this area is above the landscape and fencing would be down below the road and out of the immediate viewshed of motorists on the highway. If the officials and trustees are amenable to fences or berms, or to changes to the haying regime, such as eliminating the agriculture practice of growing grasses here and mowing them as other park areas are mowed, these strategies would greatly help the risk of white-tailed deer WVCs in this stretch and help to make the road safer for motorists.

An additional optional recommendation would be to add 0.7 miles of fence on both sides of the road along this stretch. It is understood that the trustees of the James Foundation or the Park managers may not agree to placing the wing fences to guide deer to the existing bridges. If there are problems with these fences, placement of guard rails to deter deer movement over the road should be considered. It should be noted that 73 percent of all crashes along this stretch were with wildlife, thus the white-tailed deer usage of the road for movement is a problem for motorists and should not be overlooked when debating fences.

6.9.2.1 MERAMEC RIVER BRIDGE – MO-8 EAST – MP 8.3

The floodplain of this river has been expanded during recent flooding. The widened floodplain provides pathways along the river where wildlife and humans can traverse beneath MO-8. This is likely an important waterway access point for recreationists.

Figure 6-67: Meramec River Bridge at MP 8.3.



Short Term Actions

Clear vegetation or provide a path in the rock and concrete under the bridge at the bridge approaches in all directions and as close as possible to the upper bridge abutments to allow white-tailed deer, other wildlife, and human access. During periods of flooding, these pathways are critical to terrestrial movement and thus should be located upslope, close to the bridge abutments.

Figure 6-68: Flooded conditions obscuring access beneath the bridge.



Retrofit Infrastructure

Place wing fences from the west side of the bridge only to help guide white-tailed deer and other wildlife to the bridge area. No fences should be placed on the east side of the bridge; the area is very steep and no WVCs were reported in this area.

- Total Fence –1,960 feet
 - Northwest Fence – 1,011 feet, angled away from the river avoid the ROW fence due to flooding potential.
 - Southwest Fence – 949 feet, extend to Mound Ridge Road and angle fence away from road to keep it out of the floodplain when attaching to ROW fence.
- Gates – Two placed on each side of the highway in the fence to allow recreationists access the river.
- Escape Ramps – Two placed at the two sides of the bridge abutments.

6.9.2.2 MO-8 UNNAMED TRIBUTARY TO THE MERAMEC RIVER – MP 7.48

This bridge is less than 400 feet from the park entrance. If the recommended fence (discussed below) is not acceptable to the park managers and trustees, an alternative way to keep white-tailed deer off the road here will need to be explored. This area appeared to be readily flooded, though not as significantly as the Meramec River.

Figure 6-69: Unnamed Tributary to the Meramec River at MP 7.48.



Short Term Actions

Clear the vegetation in the ROW on the south side of MO-8 from County Road 3600 to the park entrance. This will help eastbound drivers see the potential for WVCs when coming around the curve. Maintain brush cutting along the ROW annually to help keep clear lines of site for drivers and white-tailed deer.

Retrofit Infrastructure

This bridge is high enough to allow white-tailed deer and human passage, and the area is wide enough to provide a diversity of dry and aquatic connectivity.

- Total Fence –3,510 feet
 - Northwest Fence (To Park Entrance) – 404 feet, extend to park entrance.
 - Northwest Fence (Past Park Entrance) – 1,146 feet, extend westward from park entrance to across from County Road 3600.
 - Southwest Fence – 1,673 feet, extend to County Road 3600.
- Escape Ramps – Three
 - Two west of the park entrance, near the west end of the fence.



- One at the bridge abutment on the south side of the road.
- Gates – Four
 - Two adjacent to park entrance.
 - One near bridge.
 - One to the west in preferred location for ROW mowing access.
- Double Cattle Guard – One double-sized double cattle guard at park entrance.

Expected reduction of WVCs to be approximately 50 percent.

A secondary option would be to extend fences to be continuous between the bridges. With this option, a fence should be placed along the highway from the unnamed tributary bridge eastward to the Meramec River bridge, encompassing a half-mile section of road adjacent to hay fields to the north that was not part of the original recommendations. If the goal of the mitigation is to reduce the WVCs significantly, and assuming the fence would not be unwelcome by park and Trustee personnel, the following additional fence should be added.

- Total Fence – 7,362 feet, 0.7 miles of road containing fencing on both sides.
 - Southeast Fence – 3,626 feet, extended southeast from the unnamed tributary bridge abutment to Mount Ridge Road.
 - Northeast Fence – 3,736 feet, extended from the unnamed tributary bridge abutment to the end of the fence on the northwest side of the Meramec River bridge.
- Escape Ramps – Four
- Gates – Two, for miscellaneous access
- Driveway Double Cattle Guard – One, next to the southeast corner of the bridge, to accommodate the park maintenance road.
- Road Double Cattle Guard – One on Mound Ridge Road

Expected reduction of WVCs for the secondary mitigation option to be approximately 85 percent.

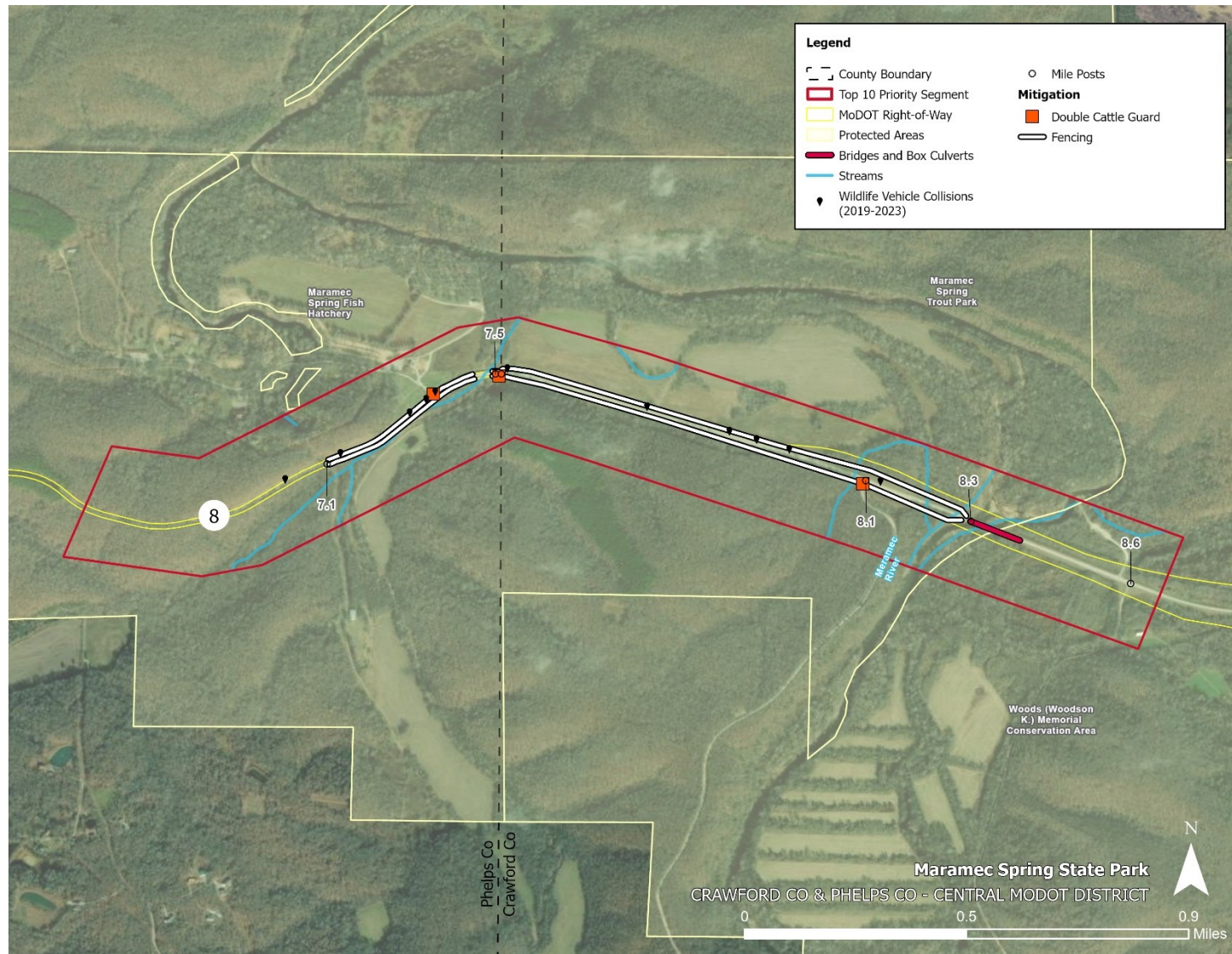
6.9.2.3 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-43** and depicted in **Figure 6-70**.

Table 6-43: Maramec Spring State Park Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
MO-8 East Meramec River Bridge – A4966 	8.3	Clear a path in the rock and concrete under the bridge as close as possible to the upper bridge abutments.	Place fence off of west corners of the bridge abutment. Extend northwest fence about 1,011 feet and southwest fence about 949 feet. Add two gates for recreational access.	None
MO-8 Unnamed Tributary to the Meramec River – A4962 	7.48	Clear the vegetation in the ROW on the south side of MO-8 from CR 3600 on the south side of the highway to the park entrance to improve line-of-sight distance.	Place fence off west side of bridge. Extend northwest fence about 404 feet, plus an additional 1,146 feet past entrance to park. Extend southwest fence about 1,673 feet. Add four gates, three escape ramps, and one double cattle guard. Optional Additions: Add southeast fence and extend 3,626 feet to Mound Ridge Road. Add northeast fence and extend 3,736 feet. Add two gates, four escape ramps, and 3 double cattle guards.	None

Figure 6-70: Maramec Spring State Park Mitigation Recommendations.





6.9.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. Two scenarios were evaluated, one without optional additions and the other with. Without the additions, the benefit cost ratio was 2.44 with a payback period of 20.5 years. Including the optional additions dropped the benefit-cost ratio to 1.19 with an increased payback period of 24.6 years.

Table 6-44: Maramec Spring State Park Estimates for Costs of Infrastructure, Excluding Optional Additions.

Item Number	Quantity	Cost per Item	Total Cost
Fence	5,183	\$30 per linear foot	\$155,490
Gates	8	\$1,500	\$12,000
Escape Ramps	5	\$22,000	\$110,000
Road Double Cattle Guards 32 foot	1	\$78,000	\$78,000
Materials Total	--	--	\$355,490
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$405,490

Table 6-45: Maramec Spring State Park WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO crashes	11	\$15,956	\$175,516	--
Minor Injury	0	\$204,700	0	--
Serious or Disabling Injury	0	\$787,600	0	--
Total Costs	--	--	--	\$175,516
Total Costs per Year	--	--	--	\$35,103

Table 6-46: Maramec Spring State Park Benefit Cost Ratio Calculations, Reduced Fence Length.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	$(35,103 + (2,000 \times 2.2)) \times 0.50 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	$355,490 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$987,580	\$405,490	2.44	20.5 years



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Table 6-47: Maramec Spring State Park Estimates for Costs of Infrastructure, Including Optional Fence Addition.

Item Number	Quantity	Cost per Item	Total Cost
Fence	12,545	\$30 per linear foot	\$376,350
Gate	8	\$1,500	\$12,000
Escape Ramp	9	\$22,000	\$198,000
Driveway Double Cattle Guard 16 foot	1	\$35,000	\$35,000
Road Double Cattle Guard 32 foot	2	\$78,000	\$156,000
Materials Total	--	--	\$777,350
Maintenance	50 years	\$1,000 per year	\$50,000
Grand Total	--	--	\$827,350

Table 6-48: Maramec Spring State Park Benefit Cost Ratio Calculations, Including Optional Fence Addition.

Benefits Formula		<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>	
Benefits Values		$(35,103 + (2,000 \times 2.2)) \times 0.85 \times 50$	
Costs Formula		<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>	
Costs Values		$777,350 + (1,000 \times 50)$	
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$1,678,886	\$827,350	1.19	24.6 years



6.10 Roubidoux Creek Conservation Area

6.10.1 Project Overview

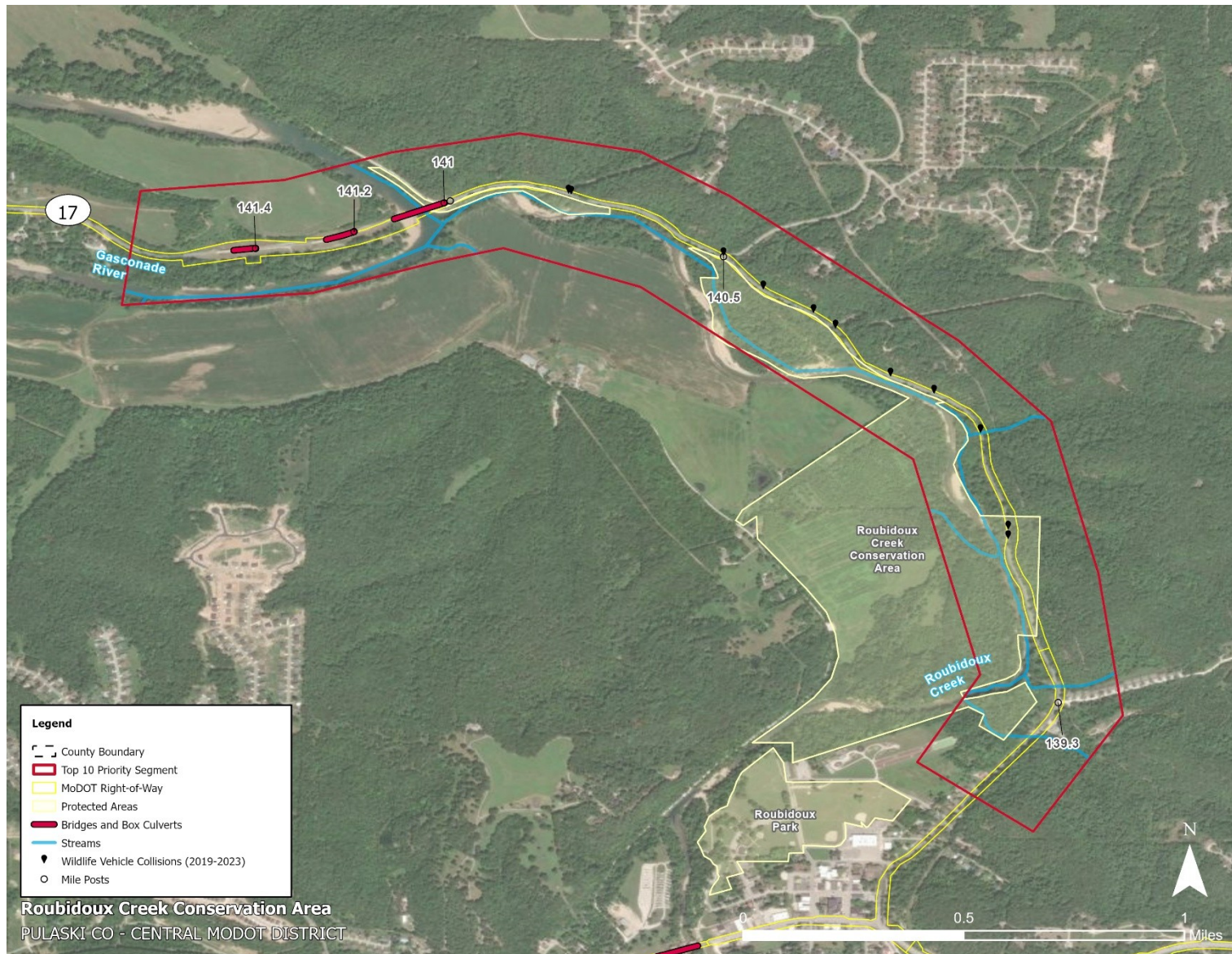
The Roubidoux Creek Conservation area lies along MO-17 just north of Waynesville, which lies just north of Interstate 44 (IS-44). This area is an anomaly in this Study due to the highway's sinuous nature and steep hills on one side of the road and a river and creek on the other. Two of the 2.5 miles of the Top 10 segment are on this steeply sloped hillside, with few options for wildlife crossing structures. Nine of the 11 reported WVCs occurred in 1.2 miles of this terrain. The road curves from the south around to east and then to the northwest. In the northwest curve, the westside lands are largely owned and managed by the Missouri Department of Conservation and form the Roubidoux Creek Conservation Area. The Gasconade River and the Roubidoux Creek flooded to extremely high levels in 2019; the field investigation noted tree debris in the bottom supports of the MO-17 bridge over the river, at least 20 feet above normal river levels.



Table 6-49: Roubidoux Creek Conservation Area Description and Criteria

Name: Roubidoux Creek Conservation Area	
MoDOT District: Central	
County: Pulaski	
Road and Mile Posts: MO-17 MP 139 – 141.5	
Total Miles: 2.5	
STIP Description: None	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	11
Wildlife Crashes per Mile per Year	0.88
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	20%
<i>Ecological</i>	
AADT	6,180
Occupied Habitat	Up to 3 priority species known to occur.
Predicted Suitable Habitat	Up to 17 priority species including: black-tailed jackrabbit, eastern tiger salamander, American badger, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, alligator snapping turtle.
MDC CCS Management Tiers	Gasconade River – Tier 2, Gasconade River Hills – Tier 3
Named Streams	Roubidoux Creek, Gasconade River
Bridges and Culverts	3 bridges
<i>Feasibility</i>	
Land Use	16% Developed
Protected Areas	Roubidoux Creek Conservation Area
<i>Qualitative Review</i>	
Constructability	2.67
Land Use	3
STIP Rating	0

Figure 6-71: Roubidoux Creek Conservation Area Overview Map.



6.10.2 Recommendations

Fencing placed along the 1.2 miles of steep curves where the nine past WVCs occurred may isolate critical resources for wildlife on both sides of the highway: the water and riparian area downhill to the west, and uplands, food resources, and shelter to the east. A 0.6-mile fence from the east side of the bridge along the curve on the steep slope is recommended to help guide deer and other wildlife to use the bridge to traverse the water and move up and down the slope to the north of the bridge. This allows wildlife movement across the road farther south but will not help the WVCs in those areas. It is expected that the AADT of 6,000+ vehicles a day are during the hours of dawn, day, and dusk, and that wildlife could cross the road in the later night hours when fewer vehicles are expected.

6.10.2.1 GASCONADE RIVER BRIDGE MO-17 N MP 141.01

The bridge is very high and wide, allowing room wildlife to pass beneath. The woody debris on the underside of the bridge, approximately 20 feet above the river height as noted during the field investigation, indicated the extent the river can flood and spread across this incised landscape. MDC owns and manages the land on the inside of the MO-17 curve, to the east of the bridge, and there is a fishing and boating access driveway that goes down to the water next to the bridge. Placing wildlife exclusion fence from this east side abutment of the bridge eastward down MO-17 approximately 0.6 miles would help to reduce WVCs in this stretch where it is difficult to see wildlife in the road due to the curve.

Figure 6-72: Gasconade River Bridge at MP 141.01.



Short Term Actions

Reduce speeds in the area through signage and possible enforcement. The field investigation noted that the speed limit is quite high for a winding rural road, potentially as high as 45 to 50 miles per hour (mph). Motorists will be better able to reduce their chances of being involved in a WVC if the speed limit was reduced to 45 mph or less.



The timing of crashes during the year should be investigated. If crashes are seasonal, mobile message boards should be posted for both directions of traffic, warning of potential wildlife on the road.

Likewise, static signs with flashing LED lights should be placed for both directions of traffic. For south bound motorists, the sign should be placed right after bridge; for north bound motorists, the sign should be placed before the curve along the Roubidoux Creek Conservation Area.

Retrofits Infrastructure

Place wildlife exclusion fence on the east side of the bridge, along with three gates and two escape ramps.

- Total Fence – 5,612 feet
 - Northeast Fence – 2,752 feet, placed on the east side of Lexington Road.
 - Southeast Fence – 2,860 feet.
- Escape Ramps – Two, one on north side and one on south side, both near a fence end.
- Gates – Three, one gate at the entrance to the fishing access, with a spring load or gravity fed, to assure gate is closed. Two gates along the fence line, one on the north side, and one on the south side for access to the uphill or creek areas, also spring loaded to assure closure.
- Double Cattle Guard – One, at the boat ramp driveway on the south side of the fenced area near the bridge.

Expected reduction of WVCs to be approximately 27 percent.

6.10.2.2 WEST OF GASCONADE RIVER BRIDGE

These two long bridges stand above the landscape in a type of viaduct that allows the Gasconade River overflow to pass beneath the highway. The west bridge is 275 feet long and is high enough to allow passage of white-tailed deer and other wildlife. With its extensive length paired with the Far West Bridge at MO-17 South MP 45.45, North MP 141.35, the white-tailed deer and other wildlife have been using the areas beneath these structures to cross the road. There were no recorded crashes with wildlife in the area near and between these two bridges. There is no need to add any wildlife mitigation actions for this area.

Figure 6-73: West of Gasconade River Bridge at MP 141.18 and 141.35.



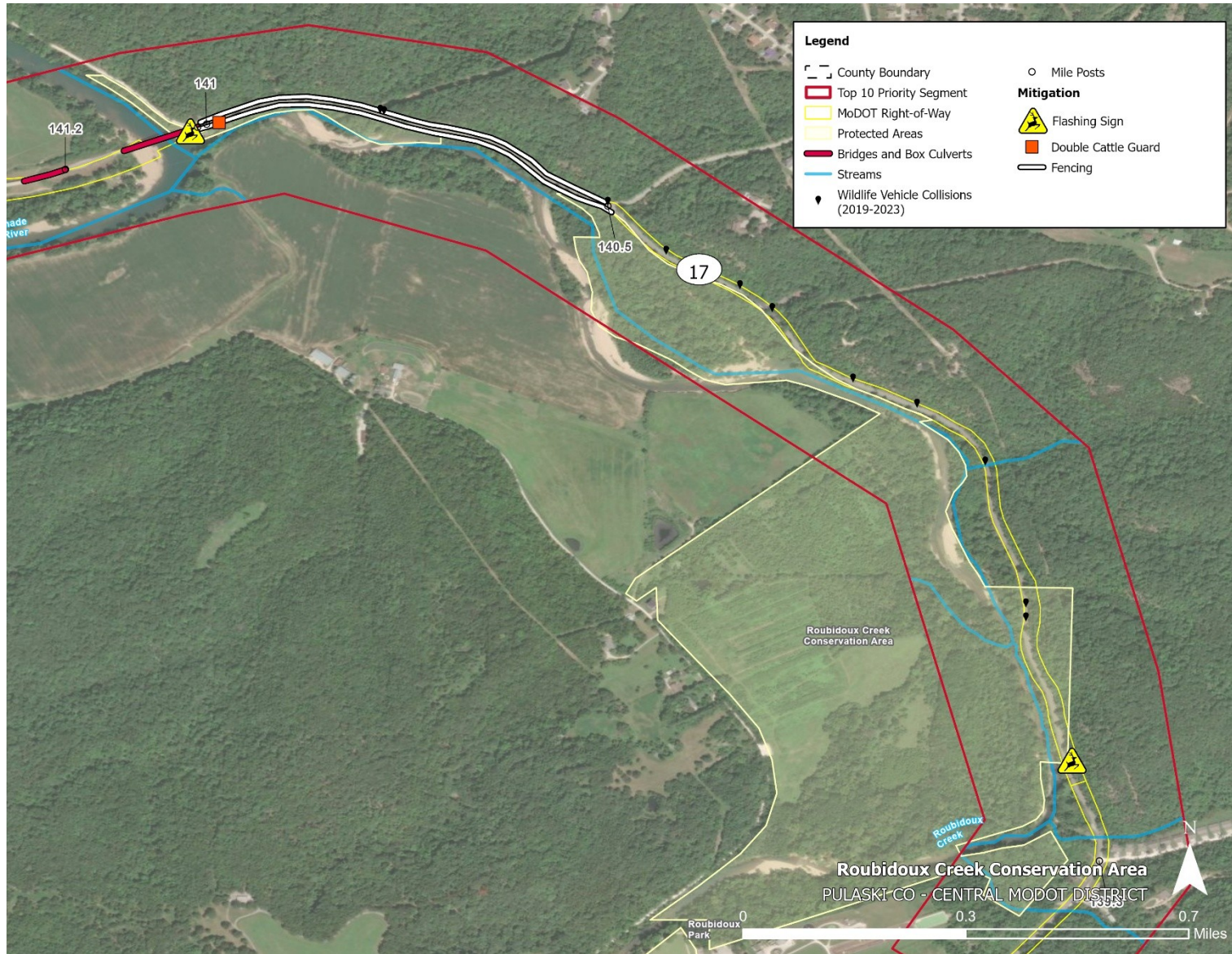
6.10.2.3 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-50** and depicted in **Figure 6-74**.

Table 6-50: Roubidoux Creek Conservation Area Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Gasconade River Bridge MO-17 North – A7086 	141.01	Reduce speed limit; Place seasonal signs warning drivers; Place static signs with LED lights at end of bridge for southbound, and before curve northbound.	Place wildlife exclusion fence from east side abutment of the bridge eastward down MO-17 approximately 2,860 feet. Add two escape ramps, three gates, and one driveway double cattle guard.	None

Figure 6-74: Roubidoux Creek Conservation Area Mitigation Recommendations.





6.10.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. At this location, the benefit-cost ratio was 7.71, with a payback period of 6.49 years.

Table 6-51: Roubidoux Creek Conservation Area Estimates for Costs of Infrastructure.

Item Number	Quantity	Cost per Item	Total Cost
Fence	5,612	\$30 per linear foot	\$168,360
Gates	3	\$1,500	\$4,500
Escape Ramps	2	\$22,000	\$44,000
Driveway Double Cattle Guards 16 foot	1	\$35,000	\$35,000
Materials Total	--	--	\$355,490
Maintenance	50 Years	\$1,000 per year	\$50,000
Grand Total	--	--	\$405,490

Table 6-52: Roubidoux Creek Conservation Area WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO Crashes	9	\$15,956	\$143,604	--
Minor Injury	1	\$204,700	\$204,700	--
Serious / Disabling Injury	1	\$787,600	\$787,600	--
Cost For 5 Years	--	--	--	\$1,135,904
Average Cost Per Year	--	--	--	\$227,181

Table 6-53: Roubidoux Creek Conservation Area Benefit Cost Ratio Calculations.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
Benefits Values	<i>(227,181 + (2,000 x 2.2)) x 0.27 x 50</i>		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
Costs Values	<i>355,490 + (1,000 x 50)</i>		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$3,126,341	\$405,490	7.71	6.49 years



6.11 Honey Creek Conservation Area

6.11.1 Project Overview

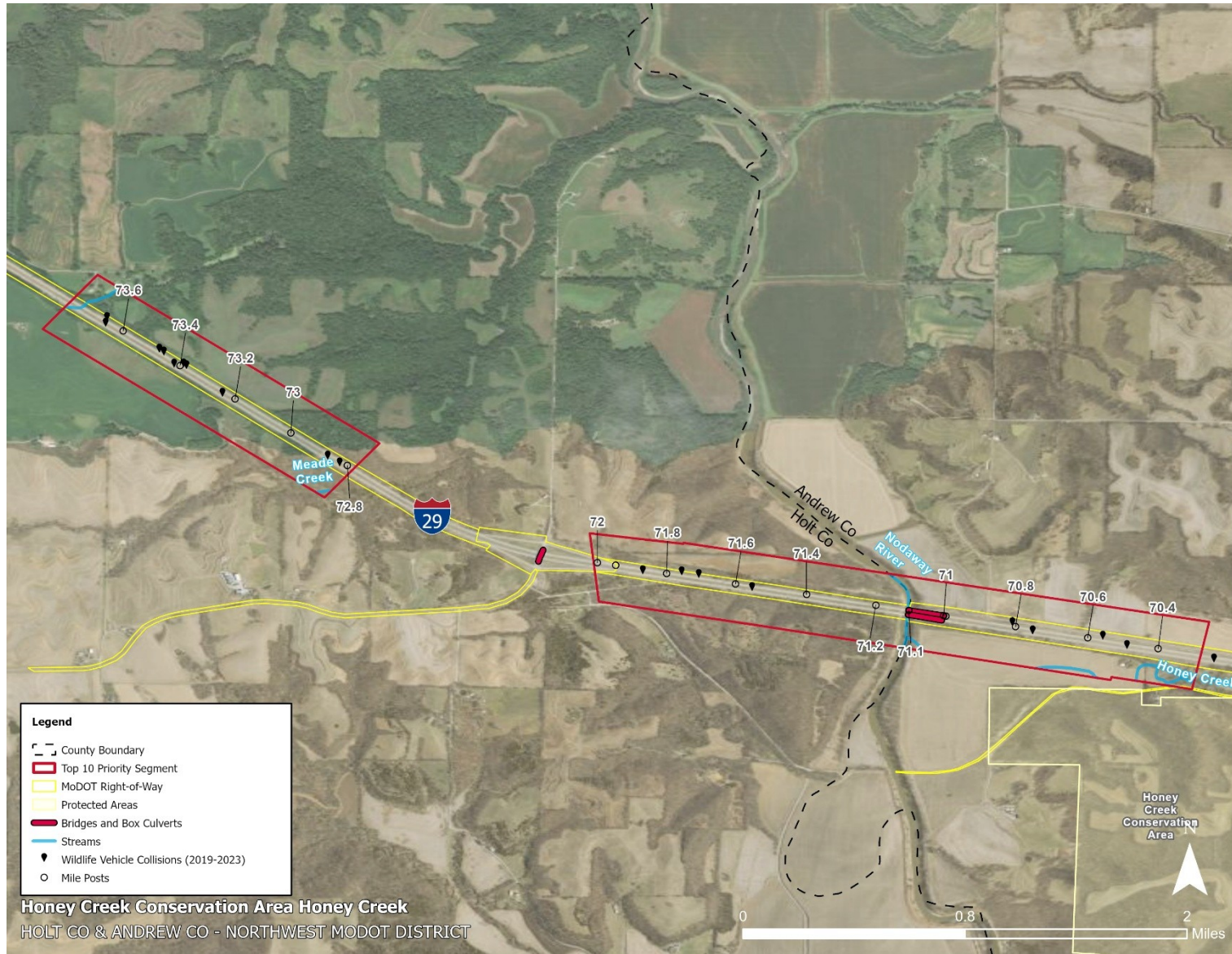
This area is north of St. Joseph along the IS-29 and Missouri River corridors. From IS-29 outward the area is rich in riparian forests and waterways. The Honey Creek Conservation Area is to the southeast of this area. This area consists of two areas on IS-29: the southern portion from MP 70 to 72; and the northern portion from MP 73 to 74, for a total of three miles. The Nodaway River runs north-south to the Missouri River through the southern portion. Land is privately owned along the entire length of IS-29 in these areas; however, the many creeks and floodplains throughout make this area somewhat unsuitable for development. Land use is predominantly agriculture and forestry. Because these waterways help to preclude human development in the area, there is potential for mitigating IS-29 to funnel deer and other wildlife to existing bridges.



Table 6-54: Honey Creek Conservation Area Description and Criteria

Name: Honey Creek Conservation Area	
MoDOT District: Northwest	
County: Holt	
Road and Mile Posts: IS-29 Mile Post 70-72; 73-74	
Total Miles: 3	
STIP Description: Pavement resurfacing from Rte. 59 to Rte. 118.	
Criteria	Values
<i>Transportation Safety</i>	
Total Wildlife-Vehicle Crashes	18
Wildlife Crashes per Mile per Year	1.2
Crashes with Fatality and/or Serious Injury	0
Percentage of All Crashes that are WVC	28%
<i>Ecological</i>	
AADT	16,349 – 19,055
Occupied Habitat	Up to 5 priority species known to occur.
Predicted Suitable Habitat	Up to 18 priority species including: black-tailed jack rabbit, eastern tiger salamander, American badger, Franklin's ground squirrel, thirteen-lined ground squirrel, Blanding's turtle, western chicken turtle, western mud snake, western fox snake, plains spotted skunk, Indiana bat, northern leopard frog, long-tailed weasel, Niangua darter, least weasel, eastern massasauga rattlesnake, bald eagle, and alligator snapping turtle.
MDC CCS Management Tiers	None
Named Streams	Nodaway River, Meade Creek, Honey Creek
Bridges and Culverts	2 bridges
<i>Feasibility</i>	
Land Use	22 – 26% Developed
Protected Areas	Honey Creek Conservation Area
<i>Qualitative Review</i>	
Constructability	2.33 – 2.67
Land Use	3
STIP Rating	0

Figure 6-75: Honey Creek Overview Map.



6.11.2 Recommendations

The Honey Creek Conservation Area presents several challenges to installing wildlife mitigation measures. First, as mentioned above, the land on both sides of IS-29 is privately owned. Secondly, due to the proximity of the Missouri River, the area has a high water table and saturated soils, making the potential for wildlife underpasses a challenge. Lastly, with only one pair of bridges between the two areas, there are limited options for placing enough wildlife exclusion fencing to direct wildlife to the bridge. The Nodaway River bridges are tall and wide, however, which presents a perfect opportunity to guide wildlife to them with wildlife fencing.

The southern portion has a pair of high multi-span bridges over the Nodaway River running through the middle of this area. The bridges extend for hundreds of feet to the south, allowing for seasonal floodwater and local wildlife to move beneath the highway. Many white-tailed deer tracks were noted below the bridges during the field investigation, indicating that the local animals already know how to move beneath the structure. If one mile of fence was placed to the south, from the point where the bridges are close to the ground and deer could not move beneath them, it would extend to the County Road 72 interchange. The northern end of the bridges could have fence placed 0.45 miles north. These fences, along with the bridge, would reduce WVCs by approximately 50 percent for the entire area within the southern portion.

The northern portion, from IS-29 MP 73-74, had 10 recorded crashes with wildlife over a five-year period. This equates to two crashes per mile per year, making it a high crash rate area. Unfortunately, there are no existing bridges or large culverts to allow white-tailed deer to move beneath the highway. A fence placed along this 1-mile stretch, with no structures for passage, would almost certainly move the WVC problem to the fence ends. The only long-term solution would be to place a wildlife underpass at approximately MP 73.4 or replace the un-recorded Meade Creek Culvert at S MP 73.7 (**Appendix I**). One of these structures, along with 0.25 miles of fence in each direction from either culvert, could reduce the reported crashes by 80 to 90 percent. The pair of new culverts for a wildlife underpass at MP 73.4 was the recommended mitigation method. The benefit-cost analysis of the recommended mitigation with and without the paired underpass culverts showed benefit ratios above 1 for both options. It should be noted in MoDOT records that these recommendations should be considered when the road has an upcoming project in the area; the new structures are not included in the final benefit-cost analysis.

6.11.2.1 IS-29 NODAWAY RIVER BRIDGE – MP 71.1

The pair of bridges over Nodaway River are approximately 20 feet above the river and its 100-year floodplain, making it a perfect area for wildlife to move beneath the bridge. The field investigation documented many different kinds of wildlife tracks under the bridge, particularly small and medium-sized mammals. A female white-tailed deer swam the river during the investigation. There are, however, canals/ditches parallel to IS-29 coming off the river on the southeast side of the bridges, and a nearby deep ravine/ditch, which make it difficult for wildlife to negotiate these additional water features. There is evidence of erosion, and a cost-effective solution would be to place erosion control netting to slow erosion and slope degradation, so that animals can continue to use the slopes beneath the bridge.

Short Term Actions

Place erosion control netting on the slopes of the terrestrial area under the bridges to reduce the erosion coming from water flowing off the highway.

Retrofit Infrastructure

Wildlife exclusion fencing should be placed from bridge abutments eastward and westward. The fences on the southeast of these bridges should be placed at points where the bridge is low enough that deer could jump up onto the highway from the landscape, approximately where, on the north side of the highway, parallel County Road 73 turns away from IS-29 and extends northward. The length of fence would be approximately 5,600 feet, or about one mile. Seven of the nine reported WVCs in this Top 10 segment are in the area proposed for fencing.

Unfortunately, the Honey Creek Conservation Area to the south would not have direct access to the Nodaway River bridge. Animals coming from the Conservation Area would find a wildlife-exclusion fence at the nearest locations to IS-29 and would have to travel westward to get to the Nodaway River passage.

The fence on the northwest side of the bridge would extend from the northwest bridge abutments, northwestward for approximately 0.45 miles along IS-29. The fence would end where the nearby landscape is more open and has fewer trees. Areas that provide access by wildlife to the underside of the bridge should not be fenced off. Overall, mitigation is expected to reduce WVCs by 50 percent.

- Fencing –16,267 feet
 - Northwest Fence – 2,451 feet
 - Southwest Fence – 2,441 feet
 - Southeast Fence – 5,671 feet
 - Northeast Fence – 5,622 feet
 - North Median Fence – 45 feet
 - South Median Fence – 37 feet
- Escape Ramps – Six, two on northwest side, four on southeast side.
- Gates – Four to access area by bridge for mowing.

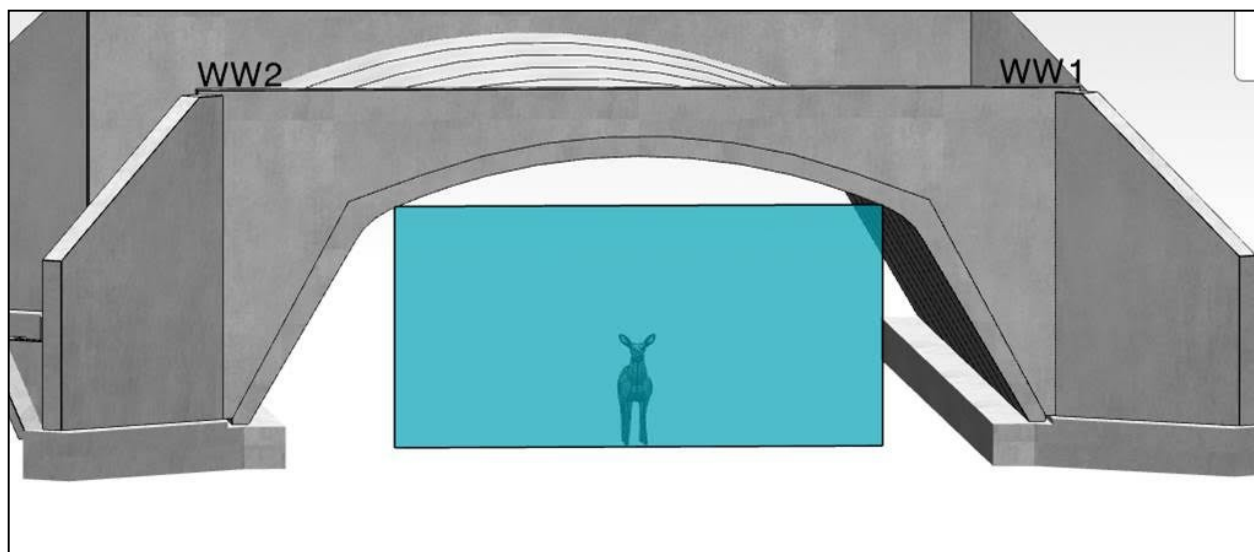
6.11.2.2 IS-29 NEW UNDERPASS – MP 73.4

Infrastructure Solutions

In a one-eighth-mile stretch within the Top 10 segment, there were five reported WVCs. This area should receive a new wildlife underpass. The current data on crashes may not be enough to warrant a structure, but it should be noted that one is recommended along with at least 0.25 miles of wildlife fence extending out from each corner of the new structure. This would eliminate eight out of the 10 total WVCs in this Top 10 segment if the fence extended 0.25 miles in each direction.

Below, a Contech figure is presented for a potential arch underpass under two lanes of highway, with a second identical one for the opposing lanes of highway (**Figure 6-76**).

Figure 6-76: Contech wildlife underpass structure under two lanes of highway¹.



¹WW = Wing wall

- Total Fence – 5,284 feet
 - Northwest Fence – 1,282 feet
 - Southwest Fence – 1,275 feet
 - Southeast Fence – 1,300 feet
 - Northeast Fence – 1,300 feet
 - North Median Fence – 63 feet
 - South Median Fence – 64 feet
- Gates – Four to access area by underpass for mowing.
- Contech pair of underpasses

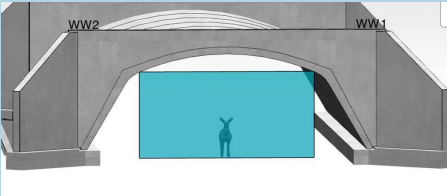
6.11.2.3 IS-29 MEADE CREEK CULVERT REPLACEMENT – MP 73.9

This culvert is not classified as a bridge and therefore not depicted in the MoDOT dataset. When the culvert is replaced, it should be replaced with a wildlife crossing culvert, which would be much larger, at least 8 feet high by 8 feet wide, but preferably 10 feet high and wide at a minimum, and large enough to accommodate both aquatic and terrestrial species' movement. There should also be an open median, meaning two culverts would be needed at this location.

6.11.2.4 RECOMMENDATION SUMMARY

A summary of the proposed mitigation is included in **Table 6-55** and depicted in **Figure 6-77** and **Figure 6-78**

Table 6-55: Honey Creek Conservation Area Overview Table of Recommended Mitigation and Accommodation Strategies.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
Nodaway River Bridge – G0490 & A1287 	71.14	Place erosion control netting to help prevent slope degradation, and to prevent wildlife from using the slopes beneath the bridge.	Place fence lines off of the northwest corner of the bridge abutment and extend for about 2,450 feet. Place southeast fences where deer can no longer move beneath the bridge for about 5,650 feet. Extend fence southeast to the entrance and exit ramps at County Road 72. Add four gates and six escape ramps.	None
New Underpasses IS-29 	73.4	None	None	In the future, install a wildlife underpass – either culvert, bridge, or arch culvert. Keep median open. Place 1,320 feet of fences off of each corner in each direction.
Meade Creek Culvert IS-29	73.9	None	None	In the future, install a larger box culvert when the existing culvert is replaced. Places fence 2,640 feet in each direction off of the new culvert.

Location	Mile Post	Short Term Actions	Retrofit Existing Structures	Infrastructure Solutions
				

Figure 6-77: Honey Creek Conservation Area, South, Mitigation Map.

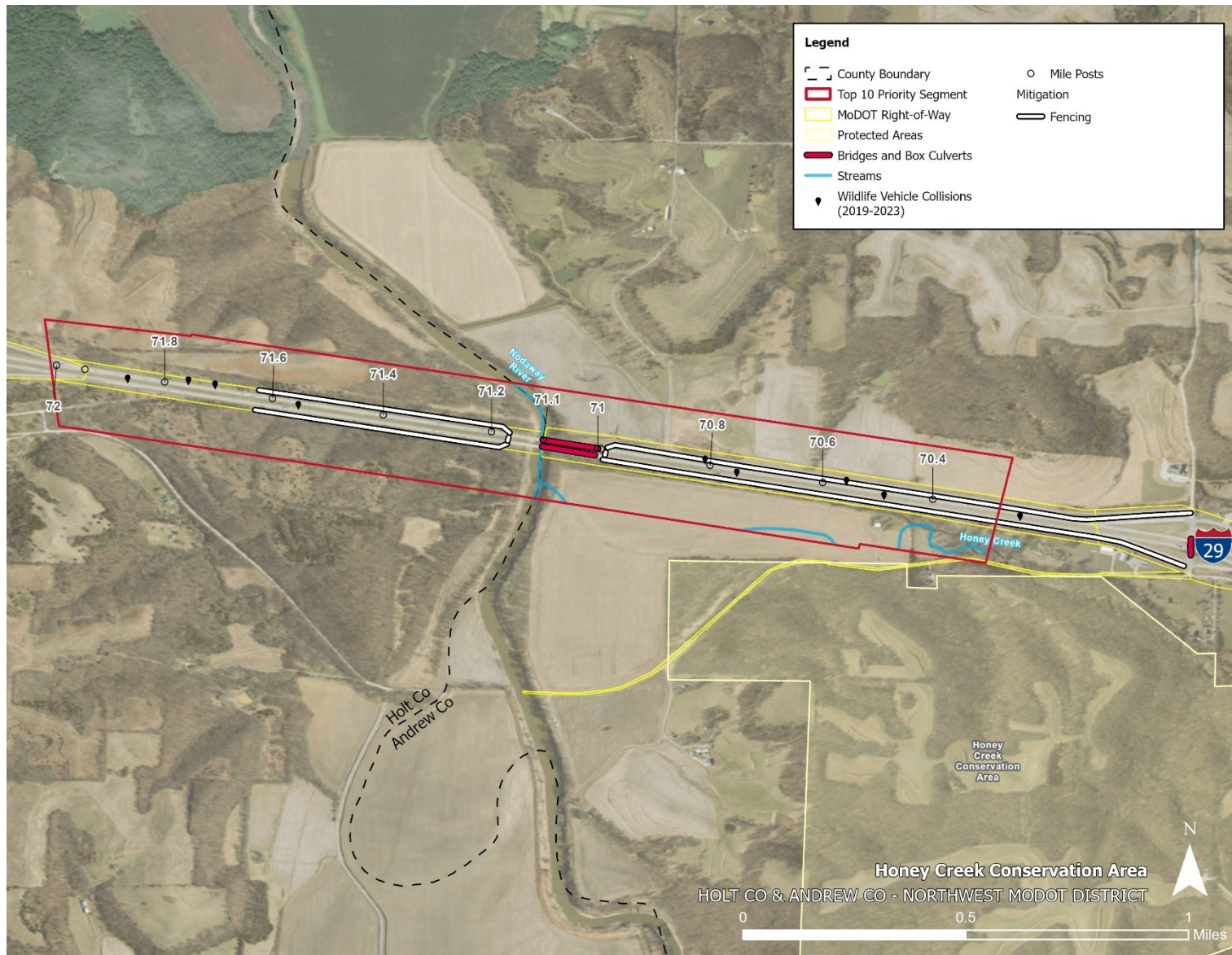
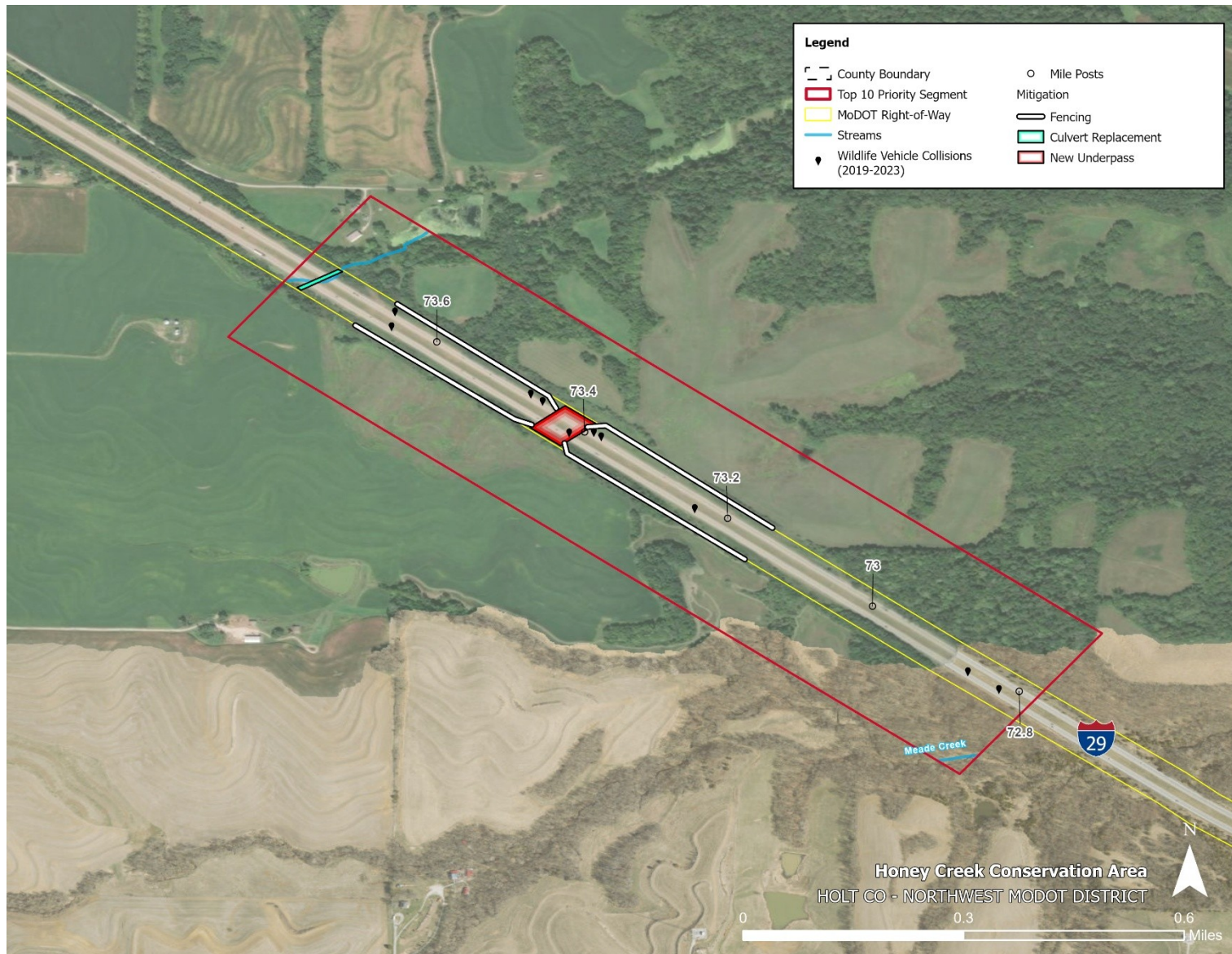


Figure 6-78: Honey Creek Conservation Area, North, Mitigation Map.





6.11.3 Benefit-Cost Analysis

The total infrastructure costs, WVC crash costs, and benefit cost calculations are summarized in the tables below. Two scenarios were evaluated, one without two new underpasses and the other with. Without the underpasses, the benefit cost ratio was 2.46 with a payback period of 20.3 years. Including the underpasses dropped the benefit cost ratio to 1.54 with an increased payback period of 34.6 years.

Table 6-56: Honey Creek Conservation Area Estimates for Costs of Infrastructure, Excluding New Underpasses.

Item Number	Quantity	Cost per Item	Total Cost
Fence	16,267 feet	\$30 per linear foot	\$488,010
Gate	4	\$1,500	\$6,000
Escape Ramp	6	\$22,000	\$132,000
Materials Total	--	--	\$626,010
Maintenance	50 years	\$1,000 per year	\$50,000
Grand Total	--	--	\$676,010

Table 6-57: Honey Creek Conservation Area WVC Costs Based on 2019-2023 Crash Data.

Crash Type	Total Crashes	Average Cost Per Crash	Total Cost for Crash Types	Total Cost
PDO crashes	7	\$15,956	\$111,692	--
Minor Injury	1	\$204,700	\$204,700	--
Serious or Disabling Injury	0	\$787,600	0	--
Total Costs	--	--	--	\$316,392
Total Costs per Year	--	--	--	\$63,278

Table 6-58: Honey Creek Conservation Area Benefit Cost Ratio Calculations, Excluding New Underpasses.

Benefits Formula		<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>	
Benefits Values	(63,278 + (2,000 x 1.6)) x 0.50 x 50		
Costs Formula		<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>	
Costs Values	626,010 + (1,000 x 50)		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$1,661,960	\$676,010	2.46	20.3 years



Missouri Statewide Wildlife Vehicle Collision Study
Alternatives Analysis and Recommended Improvements

Table 6-59: Honey Creek Conservation Area Estimates for Costs of Infrastructure, Including New Underpasses.

Item Number	Quantity	Cost per Item	Total Cost
Fence	21,551 feet	\$30 per linear foot	\$646,530
Gate	8	\$1,500	\$12,000
Escape Ramp	6	\$22,000	\$132,000
Contech Arch Culverts	2	\$500,000	\$1,000,000
Materials Total	--	--	\$1,790,530
Maintenance	50 years	\$1,000 per year	\$50,000
Grand Total	--	--	\$1,790,530

Table 6-60: Honey Creek Conservation Area Benefit Cost Ratio Calculations, Including New Underpasses.

Benefits Formula	<i>(Average Wildlife Crash Costs per Year + Wildlife Value) x Percent Reduction x Years</i>		
	$(63,278 + 3,200) \times 0.80 \times 50$		
Costs Formula	<i>Mitigation Infrastructure Costs + (Annual Maintenance Costs x Number of Years)</i>		
	$1,790,530 + (1,000 \times 50)$		
Benefits Total	Costs Total	Ratio (B / C)	Payback Period = Costs / Annual Benefit
\$2,659,136	\$1,840,530	1.44	34.6 years

6.12 Recommended Strategies for Monitoring Mitigation Measures to Assess Effectiveness

Evaluating mitigation infrastructure begins with a monitoring plan, and the results continue to inform DOT and other agency actions. These plans should be conducted in coordination with the transportation agency and wildlife researchers familiar with how to conduct these transportation ecology research projects. The monitoring plan should include pre- and post-mitigation monitoring of the project along with control areas monitored during the same period to make the strongest inferences, referred to as Before-After-Control-Impact (BACI). An example of pre-mitigation camera trap monitoring at an existing bridge is depicted below.

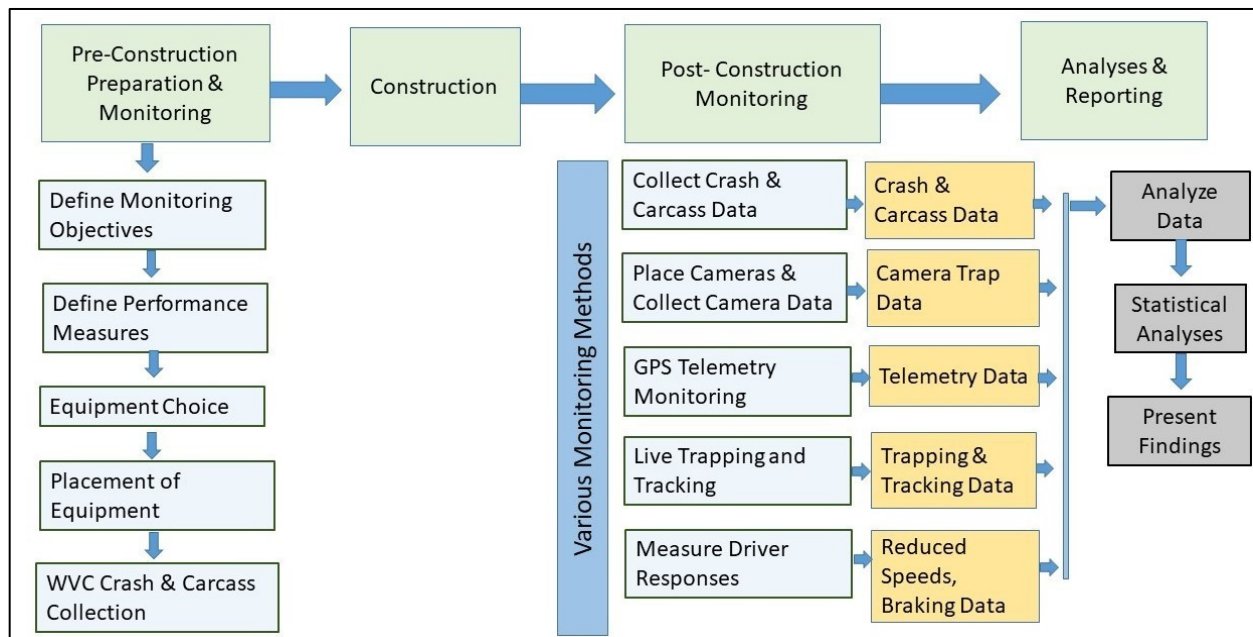
Figure 6-79: Missouri DOT's monitoring revealed deer use beneath a set of bridges.



Source: C. Knerr and MoDOT.

The following sections were largely adapted from the national manual, “The Strategic Integration of Wildlife Mitigation into Transportation Procedures: A Manual for Agencies and Partners,” (Cramer et al. 2022b) and were adapted for Missouri. The four major steps to monitoring and the inputs into a monitoring plan are presented and depicted in the flow diagram below.

Figure 6-80: Flow of steps to a monitoring program for evaluating wildlife movements in relation to transportation-wildlife mitigation.



Source: Cramer et al. 2022b.

6.12.1 Pre-Construction Preparation and Monitoring

6.12.1.1 DEFINE STUDY OBJECTIVES

Monitoring strategies to assess efficacy relies on one important question: What is the objective? Once the objectives of the monitoring are finalized, then a monitoring plan can be created, and monitoring the wildlife mitigation can begin. The strategies for monitoring are organized below based on objectives of the monitoring study for specific types of structures.

The process of researching wildlife crossing structures and other mitigation begins with what the questions are to be answered. This crystallization of the questions defines the objectives. These objectives define the type of monitoring that will occur, if pre- and post-mitigation monitoring will be conducted to evaluate changes, if there will be a control to monitor while the new changes are being monitored as well as the time period pre-change, the equipment that will be used, the length of time monitoring will be conducted, and the performance measures to evaluate the mitigation to determine if it was a “success” in meeting specific measures.

The goals of the mitigation project are defined as a first step in the process. The objectives can be seen as a series of questions, the first one being; “What is the main objective of the study?” There are typically two main objectives in studying transportation-wildlife mitigation:

1. Did mitigation improve wildlife species’ ability to move across the road and landscape?
2. Did the mitigation reduce WVCs, making the road safer for motorists?



These objectives can be further refined into specific objectives as provided below. The list is not exhaustive but presents the majority of objectives typically studied in transportation ecology. This list is based on the assumption that cameras will be used to evaluate wildlife reactions and use of structures. It also includes the evaluation of crash and carcass data.

1. What is the question?
2. What species of animals are expected to use the structures, including primary target species and other species?
3. What species of small animals and species of medium to larger animals actually use the structure?
4. Are the success rates through the structure for the species of interest high enough?
5. What species are nearby but not using the crossing structure?
6. What is the timing of species use of the structures and how does that use relate to migration and daily movement needs of those species?
7. Determine if there are components of the structures, such as type, height, width, and length that are also being tested as gauged by different species' success and repel rates.
8. Determine if the escape ramps are facilitating wildlife escape from the fenced ROW.
9. Determine if the guards, both wildlife and double cattle guards, are deterring animals from entering the fenced right-of-way.
10. Determine the data and methods to be used to compare wildlife-vehicle crash and carcass data pre- and post-construction.
11. If studying motorists' responses to animal activated detection systems, select the various factors to monitor, such as reduction of WVCs, braking responses of drivers, reduced speeds, and false positives and negatives (Cramer and Hamlin 2025b, Gagnon et al. 2019).

The way these objectives are addressed below is structured based on the type of mitigation to be monitored.

6.12.1.2 DEFINE PERFORMANCE MEASURES

The monitoring project is structured to address the various performance measures which are agreed upon prior to beginning monitoring. Performance measures should be specific and measurable; they typically delineate rates and numbers as the targets to reach. This list is not exhaustive but presents the major performance measures that are typically assessed in transportation ecology research. This list may be used as a starting point for developing performance measures for a camera trap monitoring study.

Set Rates for Defining Success at Crossing Structures

Set minimal success rates for specific species at structures, allowable repel rates, and other rates for various wildlife species at the crossing structures that would be met in the final year of monitoring, in order to determine the structure was "successful." In pre-construction monitoring, gauge the rate of specific wildlife species crossing over the existing road without crossing structures. Set a goal for a success rate, otherwise known as permeability rate, that the crossing structures should meet at minimum that exceeds that rate.

In past studies, Cramer and Hamlin (2017; 2019) found that on two-lane rural highways, with AADT at approximately 12,000 vehicles, the success rates were consistently near 68 percent for deer crossing over the highway at grade. An example of the performance measures from a Colorado State Highway 9 Study are provided below (Kinsch et al. 2021).

1. Mule deer success rates at each structure will be a minimum of 60 percent and have a goal of at least 80 percent success during the final year of the study, based on Montana (Cramer and Hamlin 2017; Cramer and Hamlin 2019), Utah (Cramer 2012; Cramer 2016), and Wyoming (Sawyer et al. 2012).
2. Success rates for all medium to large-sized mammal species (other than deer and elk) detected at each structure will be a minimum of 60 percent and have a goal of 80 percent success for each structure during the final year of the study, based on Montana (Cramer and Hamlin 2017).

Decide Acceptable Use Rates for Specific Species

Ask "What is an acceptable average daily number of successful passages of the target species through or over the structure, over the course of the final year of monitoring?" Examples from the Colorado SH-9 study are provided below (Kinsch et al. 2021).

- By the end of the study, buck and doe mule deer passages through all crossing structures will be in the same proportion of bucks and does estimated for the local population. Post-hunt population estimates were determined by Colorado Parks and Wildlife. Each year there will be an increase in the number of mule deer successful passages at wildlife crossing structures annually until an overall equilibrium/plateau is reached.

Define Species Connectivity

An important component to evaluating wildlife crossing structures or existing structures for wildlife use is to understand the types of connectivity that the structure could be expected to provide. There are three kinds of connectivity that may occur: genetic connectivity, selected connectivity, and functional connectivity. Genetic connectivity is the result of several individuals successfully crossing the road and becoming part of the breeding population on the other side. Select connectivity is when the structure acts a sieve; only some members of the population may use it. In some ungulate species, such as elk, only mature bull elk will use certain structures, and the cows and the entire herds that follow them will not. Functional connectivity is when there is evidence that the majority of a population, including all its age classes and genders, are using a structure.

A decision must be made as to what type and level of connectivity to use as a performance measure. Use rates of the structures by all age classes and genders of a species, i.e. the permeability of the road with the structures for entire populations of the species should be set. Determine the degree of permeability desired for each target species, or how many animals of the species of interest use it on average each year. Example connectivity goals are provided below (Kinsch et al. 2021).

- Each year, there will be at least one to several successful passages at the crossing structures for every one of the less common species of large ungulates and carnivores in



the study area that are documented by the habitat cameras. This may include bighorn sheep, pronghorn, moose, white-tailed deer, mountain lion, black bear, bobcat, and other species.

Define Double Cattle Guard Success

If studying deterrents such as cattle guards/wildlife guards, determine what percentage of deterrence is acceptable. As an example, “By the end of the study, at least 80% of the individual mule deer, elk and other ungulate approaches to each wildlife guard will be deterred from entering the road right-of-way” (Kinsch et al. 2021).

Define Escape Ramp Success

When studying escape ramps, the two performance measure rates that would be set to acceptable rates would be: the ramps’ rate of interception of wildlife moving in the ROW near the camera, and the rate of escape or jump off of wildlife photographed at the top of the ramp. An example of these performance measures was demonstrated in Kintsch et al. (2021), where the goal was established that by the end of the study, 50 percent of the individual mule deer and elk that ascended an escape ramp would escape to the habitat side, and no wildlife would jump up onto the ramp from the habitat side (Cramer and Hamlin 2019c).

Define Success at Fence Ends

Determine what the target decrease is, in either rates or numbers, of wildlife moving around the fence end over time. An example of this from Kintsch et al. (2021): by the end of the study, the proportion of ungulate movements at the south fence end that enter the fenced ROW will decrease to 20 percent or less. Based on Utah (Cramer and Hamlin 2019). This performance measure was not met in the Kintsch et al. 2021 study, indicating that the WVC problem was moved to the fence ends.

Define the Success of Mitigation with the Reduction of Crashes and Carcasses

Set a bar of success for the reduction in reported wildlife-vehicle crashes, or carcasses, or both, in the study area and outside the area that were not mitigated. Kintsch et al. (2021) set three metrics for defining this performance measure. The first established the goal that the annual average number of reported WVC crashes within the mitigated area of the study would decrease by at least 80 percent during the final two years of the study, when compared to the five-year pre-construction average. Based on Alberta, Canada (Clevenger and Barrueto 2014), Wyoming (Sawyer et al. 2012), and a compiled study (Huijser et al. 2009). The Kintsch et al. (2021) CO SH 9 Study exceeded this measure, reporting reductions of crashes and carcasses of over 90 percent, making this one of the most successful mitigation projects in North America.

The second established goal in Kintsch et al. (2021) stated that the annual average number of wildlife carcasses reported by Blue Valley Ranch and Colorado Parks and Wildlife within the mitigated area of the study would decrease by at least 80 percent during the final two years of the study when compared to the five-year pre-construction average.

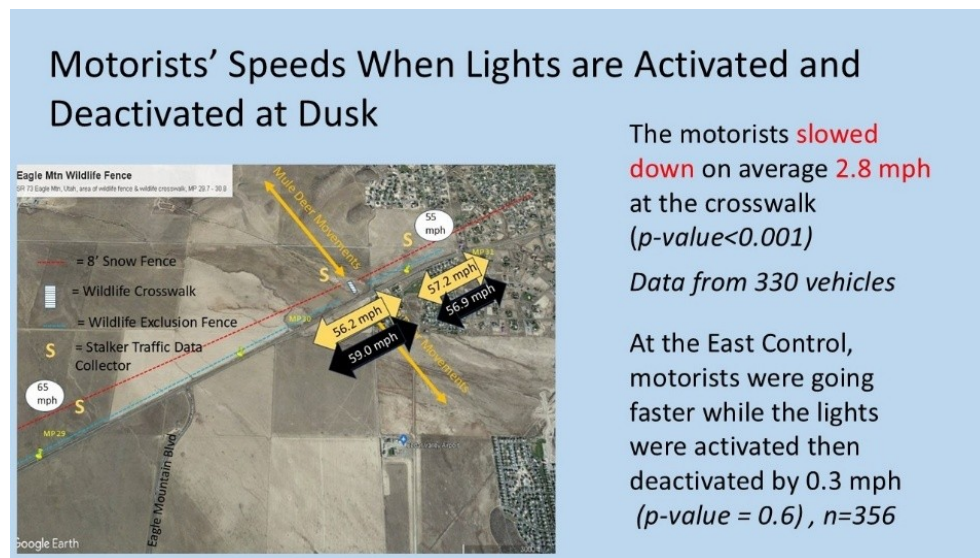
The third and final metric established in Kintsch et al. (2021) stated that by the final year of the study, the average annual number of reported WVC crashes within one mile south of the south fence end would not increase over the five-year average annual pre-construction crash rate for

this section of road. The Kintsch et al. (2021) study did not meet this measure; to some degree, the WVC problem was moved down the road.

Determine Various Success Measures for Wildlife Detection Driver Warning Systems

To monitor motorist response to wildlife detection driver warning systems (WDS) and signs, the defined goal should be the reduction of motorists' speed (**Figure 6-81**). in response to various measurable factors. These factors can include motorist response to sign warnings, the percentage of reduced crashes with wildlife, or the number of potential successful animal movements over the road. Other objectives of the system, such as rate of false positives and false negatives, days the system is in working order (reliability of the system in different conditions and over time), and time costs to maintenance personnel can also be considered (Cramer and Hamlin 2025a; Cramer and Hamlin 2025b).

Figure 6-81: An example of information on driver speeds in a wildlife crosswalk area with a WDS (both lights on and off) and speeds in a control to the east during the same conditions.



Source: Cramer and Hamlin 2025b.

6.12.1.3 SELECT EQUIPMENT FOR MONITORING BASED ON PERFORMANCE MEASURES

Identify whether the study is sampling wild animals and their movements or conducting a census of all animals and movements in an area. This determines the equipment type, such as cameras and camera quality, pitfall traps for smaller animals, telemetry equipment, etc.

If using camera monitoring, select the best quality cameras that the budget can afford and according to objectives. Multiple high-quality cameras may be necessary for photographing all the animals at the site. The cameras' method of detection, such as infrared and thermal sensors, number of pictures per trigger, or video footage will need to be determined with respect to the monitoring objectives. If conducting a census of all wildlife movement, the trigger should have no down time, and pictures per trigger should be three to 10, depending on the number of animals and the battery life of the camera.

Figure 6-82: A researcher sets up a camera at a wildlife underpass in Colorado.



Source: P. Cramer

If the objective is to live-capture smaller animals, selection of pitfall traps and live traps that match the species' sizes and modes of locomotion is critical. If using Passive Integrated Transponder (PIT) tags, size and type are important for the target species and using qualified wildlife personnel who can place these on and in the animals is crucial. Live-capture methods may also require specific permits to handle target species directly.

If using telemetry equipment, experienced wildlife researchers are necessary to help capture animals and place monitoring collars and other equipment on the animals. Selection of the type of telemetry tracking devices will involve costs, size constraints, and how many times a day the information is recorded.

6.12.1.4 PLACING EQUIPMENT

Placement of equipment can mean the difference between detecting wildlife accurately and missing wildlife movements. It also affects accuracy in recording movement rates, which are critical for reporting how well the mitigation objectives were met.

Camera Monitoring at Future Wildlife Crossing Structure Sites

For pre-construction monitoring, place cameras near the location of the future wildlife crossing structure, the existing structures, or other mitigation, positioned in such a way that wildlife approaches and movements will be captured. Pre-construction monitoring of the road-wildlife interface can help determine the successful road passage rates prior to the mitigation (Cramer

and Hamlin 2017). This rate can be used as the basis for creating a performance measure for improved successful passage and thus connectivity with crossing structures. Camera placement along roads can be a delicate operation of minimizing photographs of vehicles, protecting possible motorist crashes with camera mounts, and protecting the cameras from theft.

Camera sensitivity to nearby moving traffic should be tested continually; cameras angles and sensitivity should be set so as to avoid capturing passing vehicles, to the greatest extent possible, in order to preserve battery life. In areas with fewer than 2,000 vehicles per day, it may be possible to maintain battery life until the next monthly camera check.

Likewise, vegetation within the camera trigger range should be regularly trimmed. If monitoring through the growing season (especially during the month of June), vegetation clippers, sling blades, etc. should be brought to routine camera checks in order to cut back vegetation.

Figure 6-83: A pre-construction ROW camera recorded how often white-tailed deer successfully crossed US 93 Montana, thus helping to estimate a pre-construction success rate across the road.



Source: P. Cramer and Montana DOT

Placement of Live-Traps and Tracking

If using other methods to detect wildlife such as live traps, sand beds, or general tracking, it is important to understand how target species move and use the landscape. Place monitoring equipment in areas wildlife are likely to use in the same methods described above. These methods should be standardized across space and time; for example, equal-sized grid patterns for live traps, equal-sized track beds, etc.

Telemetry Monitoring of Wildlife

Telemetry monitoring of wildlife prior to a wildlife mitigation project helps determine how wildlife used the landscape in comparison to how they use it post-construction.

At least two years of data should be collected where possible, but preferably up to five years of pre-construction GPS movement data to obtain baseline levels of highway permeability and



distribution of locations where wildlife cross or approach the road. This is particularly important for species that show high road avoidance and low WVC incidence (Dodd et al. 2010).

6.12.1.5 DETERMINE A CONSISTENT APPROACH FOR WILDLIFE-VEHICLE COLLISION DATA COLLECTION

Prior to project implementation, select what WVC data will be collected based on the type of the project and species of interest, and use the same approach before and after project completion. For example, standard crash data may suffice for large animals like white-tailed deer, but more thorough carcass/roadkill surveys may be required for smaller animals.

Where possible, collect data within the planned mitigated area at a minimum, but preferably beyond the extent of the mitigated area to identify the potential for increased WVCs at fence ends. Also collect data in control sections of roadway, where feasible. These control areas are locations where no construction or changes are being made to the road, and the landscape conditions and wildlife activity are relatively similar to the mitigation portion of the road. A control section of the same or similar road area setup helps to discern if the changes between pre- and post-construction were a result of the mitigation, and not changes in traffic, wildlife populations, the landscape, or weather patterns.

At least two years of pre-construction reported wildlife-vehicle crash data collection is recommended to account for variation in seasonality and changes in precipitation, which can affect crash rates. It is strongly suggested that crash data be the data of choice for discerning if WVCs were reduced, although additional evaluations can be made using carcass data or roadkill survey data. Five-year crash analysis prior to construction is the standard used in transportation agencies and research and should be the goal of the monitoring study.

6.12.2 Monitoring During Mitigation Construction

Most wildlife monitoring at or near wildlife mitigation sites does not take place during construction. However, larger transportation projects may be phased over time, and construction can take place in one area of the study while other parts are being monitored pre- and post-construction (Cramer and Hamlin 2017, Kintsch et al. 2021).

Construction activities affect traffic speeds and flow, wildlife movements, and the roadbed. The construction phase should not be considered when making comparisons between pre- and post-construction WVC rates. Camera monitoring and other monitoring methods are typically not initiated until after construction is completed.

6.12.3 Post-Construction Monitoring

6.12.3.1 TIMELINE

Conduct long-term post-mitigation monitoring for at least three to four years (preferably five years) to account for wildlife adapting to mitigation and seasonal or annual variations. If monitoring can be continued past the five-year mark, the information could greatly contribute to the scientific literature of transportation ecology and assist the transportation agency in adaptive management of the infrastructure over time. Another consideration is to re-visit a wildlife mitigation project



several years after monitoring has ceased, to evaluate if the structures and other mitigation are functioning as planned.

6.12.3.2 COLLECT CRASH AND CARCASS DATA

Collect wildlife-vehicle crash and carcass data at the mitigation site and control sites using the same methods used for pre-mitigation. As with pre-construction data, five years of post-construction data is preferred for a more robust analysis.

6.12.3.3 MONITOR WILDLIFE WITH CAMERAS

Camera monitoring (camera traps) has been the standard method to evaluate wildlife movements of large and medium-sized animals at crossing structures and other mitigation features. Smaller animals are typically not detected by the motion sensors on cameras that are placed and set to capture large animal movements. Other methods for evaluating smaller wildlife movement are discussed in **Section 6.12.3.4** below.

Camera Placement at Structures

Where appropriate, collect camera or video data on use of mitigation features, including approach and crossing information to determine success and failure rates. This is also applicable to wildlife escape ramps and deterrents.

A camera placed at each end of a culvert or on each side of a bridge to monitor wildlife approaches and movements into and out of the structures is typically sufficient to calculate success rates, rates of repellency, and parallel rates. Some structures may be wider than the camera range for capturing wildlife movement at night, which is typically about 30 feet. If this is the case, additional cameras may be necessary to collect accurate data. The goal is to have the camera trigger at its maximum range in nighttime conditions, while also allowing photographic analyses to detect animals at the structure.

Monitoring cameras have been developed that can detect wildlife at greater distances than the commonly used infrared and LED flash cameras. Thermal imaging cameras detect many animals, even medium-sized mammals, up to a quarter of a mile away. These cameras cost several thousand dollars and have to be highly secured when in use. Washington DOT is using these thermal imaging video cameras to detect wildlife on an overpass and underpasses along IS-90.

Figure 6-84: Wildlife researchers place a monitoring camera at the entrance to a wildlife crossing structure in Utah, along US 89.



Source: J. Gagnon

Camera Placement at Escape Ramps

For escape ramps, place a camera along the ramp base in the ROW to detect wildlife movements and calculate rates of interception, and a camera on the wild side of the fence, facing the top of the ramp to evaluate escape rates is the standard (Kintsch et al. 2021; Cramer and Hamlin 2019b).

Figure 6-85: Cameras on the wild side of the fence capture wildlife movements at the top of the ramp and inside the fence.



Source: Arizona Game and Fish

Figure 6-86: Animal movements near the base of the escape ramp and over the top of the ramps were monitored by ROW cameras in Utah.

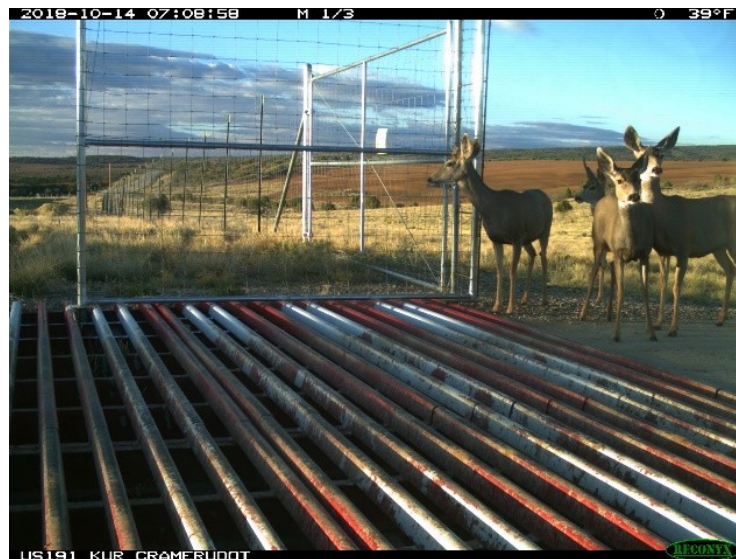


Source: P. Cramer

Camera Placement at In-Road Deterrents

Cameras placed at in-road deterrents such as double cattle guards or wildlife guards need to be placed in such a way as to record animals' initial response and final actions. The camera is placed to face the leading edge of the guard on the wild side, or the side where the animals are attempting to enter the road ROW. The goal of the camera angle is to capture animal approaches, repel movements, potential breaches, and how the animals accomplish those breaches.

Figure 6-87: Cameras at deterrents are aimed at where animal behaviors are to be evaluated. Mule deer were repelled from this double cattle guard on US 191 in Utah.



Source: P Cramer and Utah DOT

Place a Wild Camera to Assess All Wildlife Nearby

Additional cameras placed away from the crossing structures beyond the ROW, facing away from the road and out toward the wild area, are used to assess what animals are near the road but not approaching the structure. This camera is especially important for discerning if more reluctant species are present that are not using the structure. For instance, if elk are known to be in the area but are not using the structure, then the structure did not function as intended to provide connectivity for elk. This is also helpful for detecting carnivores that may be nearby and not using the structure. This has proven helpful in studies in Utah (Cramer and Hamlin 2019a) and Colorado (Cramer and Hamlin 2021; Kintsch et al. 2021).

Figure 6-88: Cameras placed away from crossing structures and toward the wild area can reveal the presence of wildlife reluctant to approach the road and structures, such as this black bear near US 93 in Montana.



Source: P. Cramer and Montana DOT

Placing Cameras at Fence Ends

The evaluation of fence ends is conducted with cameras positioned to photograph wildlife coming around the fence end. This camera placement is very difficult because the mounts for the camera have to be American Association of State Transportation Officials standard to break away when hit by a vehicle, in order to protect the vehicle occupants of the crash. The camera also has to be positioned so vehicles are not detected and photographed. The goal is to obtain photos like the figure below, where researchers can count the number and species of animals moving around the fence end, and to see if the animals cross the road or move into the fenced ROW. A paired camera at the fence end on the opposite side of the road is necessary to help make that determination. Another camera positioned along the fence outside of the ROW and inside the wild area can also photograph wildlife moving along the fence line.

Figure 6-89: Mule deer attempting to cross SH 9 at-grade, just beyond the south fence end.



Source: Kintsch et al. 2019

Protect Cameras from Vandals

Fortifications of cameras placed in these studies are needed to deter vandals. The camera will need to be locked to the mount to prevent the camera, and its entire mounting, from being stolen. This entails locks with protected clasps, steel boxes, mounts on concrete structures, and mounts solidified in concrete in the ground.

Figure 6-90: Camera mounting options: top left - on steel posts mounted in concrete; top right - on concrete wing walls of culvert; lower right - on posts of guard rails; and lower left – in a utility box.



Source: Top left and lower left - P. Cramer. Top right and lower right - J. Gagnon.

6.12.3.4 MONITORING FOR SMALL WILDLIFE

Small animal monitoring can entail the use of cameras, live trapping and marking with ear tags or PIT tags, placing telemetry transmitters on animals and releasing for telemetry monitoring, genetic sampling of small samples of the animals, environmental DNA analysis for detection of specific animal presence in aquatic environments, and road surveys for tracking carcasses (Smith et al. 2015; Clevenger and Huijser 2011; McDiarmid et al. 2012; Cramer et al. 2022b).

6.12.3.5 TELEMETRY DATA COLLECTION

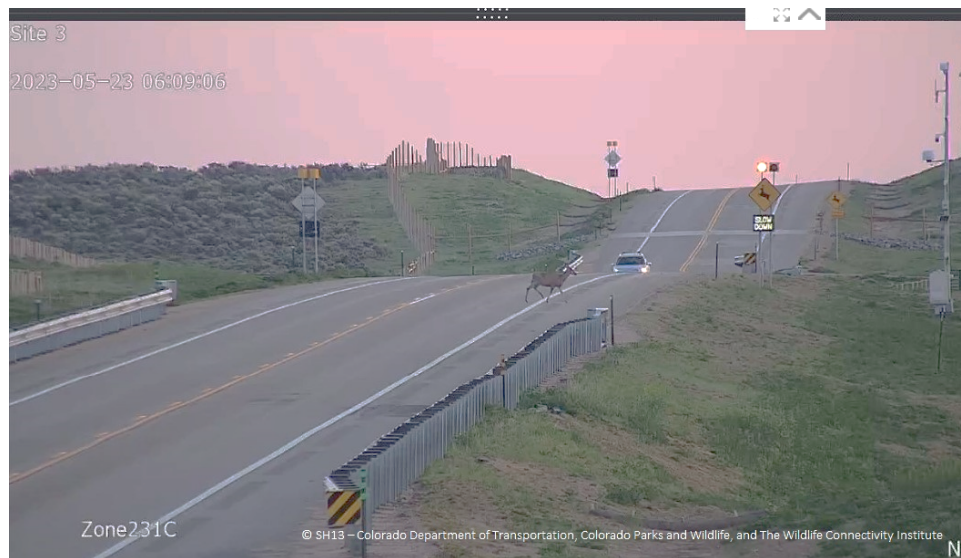
Telemetry data collection is another accurate method to detect how animals move in relation to the road. Capture and tracking methods are not covered in this Study; however, there are references to several studies, particularly in Arizona, where researchers have placed GPS collars on wildlife to track their movements near roads. Where possible, it is advised to collect additional

GPS movement data to assess levels of post-mitigation highway permeability and distribution of crossing locations. If GPS movement data were collected pre-mitigation, then permeability can be compared to determine if any changes occurred in highway (Gagnon et al. 2013; Gagnon et al. 2014; Gagnon et al. 2017).

6.12.3.6 DRIVER RESPONSE TO WARNING SYSTEMS DATA COLLECTION

WDS are placed along two-lane highways with less than 10,000 AADT where wildlife are crossing over the road at-grade. The systems use various technologies such as thermal imaging cameras, radar, and computers to process the data and control when to turn on and off the WDS, which are typically LED based lights, or flashing amber lights (**Figure 6-91**).

Figure 6-91: Mule deer move across Colorado's SH 13 in zone where a WDS is placed.



Source: Colorado DOT, Colorado Parks and Wildlife, and Wildlife Connectivity Institute

There are several methods to evaluate the efficacy of these systems, including the reduction of reported crashes with wildlife and reported carcasses, the reduction in speed of motorists as they entered the warning zone when compared to control areas, and the systems sign activation when compared to independent photos of wildlife entering the ROW. It is important to compare driver responses to the system with a control area nearby but out of the view of the system, during the exact time periods the drivers' responses are measured when in the WDS zone. This is done with radar detectors mounted on posts (done in coordination with the DOT). It is important to note that the standard traffic data collectors average vehicle speeds over a period of time and cannot give accurate readings for specific vehicles. This limitation means that the data are averaged over time and space (Cramer and Hamlin 2025a; Cramer and Hamlin 2025b).

6.12.4 Analyses and Reporting

Once the data are collected, the difficult portion of monitoring begins. This includes the tasks of categorizing and analyzing thousands to millions of photos and/or telemetry data points, along with crash or carcass data. How the data are analyzed and presented is important; the results could empower or detract from a wildlife mitigation program. The scientific investigators will need

to be completely truthful and present multiple views of looking at the data and results, and what they mean for future wildlife mitigation. The following discussion outlines how photo analyses should be conducted, how telemetry data can be analyzed and presented, how smaller animal studies present data, and how statistical analyses have been used in the past to analyze wildlife and WVC data.

6.12.4.1 PHOTO ANALYSES

Rates of Structure Use

Photo analyses have traditionally been conducted by wildlife ecologists parsing through photographic data. While automated tasks can relieve the burden of initial photo processing, much is to be learned from careful review of wildlife images. Animal reactions, interactions, and counts individual animal behaviors should be reviewed by trained wildlife scientists who are able to interpret these behaviors.

To capture success and failure rates (also called successful passage and repel rates, respectively), the number of animals that approach a feature and the number that actually use the feature or are repelled by it should be captured. Dividing the number of uses by approaches calculates the success rate ($\text{successes}/\text{approaches} = \text{success rate}$). For example, if 100 deer approach a culvert and only 50 deer cross through the culvert, the success rate is 50 percent. Viewing the inverse of this calculation (the failure or repel rate) can be more informative for infrastructure. For example, if 100 deer approach a cattle guard to access the road ROW and 10 deer cross the guard, the repel rate is 90 percent ($10 \text{ crossings}/100 \text{ approaches}$).

These rates not only help normalize wildlife response to measures to provide a consistent comparison but also work across different population densities of the same species. For example, in an area with a higher density of deer, if 1,000 deer approach an underpass and 300 deer cross through, the mitigation has a 30 percent success rate. However, if in an area with lower densities documented 100 deer approaches and 30 deer using the structure, the structure is equally effective with a success rate of 30 percent, even though the first structure has 10 times the number of crossings as the second. This conclusion (the structures used by 30 deer and 300 deer were equally effective) would have been impossible to make without collecting usage rates versus simple counts of structure use.

It is also important to consider wildlife responses to the structure that are just parallel movements without the intent of structure use. Although these rates are typically around 10 percent or lower (Cramer and Hamlin 2019a; Kintsch et al. 2021), it is still important to document animals grazing or walking along the fence line and past the structure rather than trying to move through the structure.

Success and failure rates are especially important for smaller structures, novel features, or species where little to no prior research has been conducted on their use of crossing structures. There are instances, however, when detailed monitoring data may not be cost-effective, such as at large viaducts and bridges spanning natural areas. In these instances, simple documentation

of use still provides a relative measure of success that can be compared to nearby structures within the same wildlife population densities.

Additionally, for many cases, the road ecology of structures such as large bridges over streams have been thoroughly researched to provide enough to support their use as passages for most wildlife species, and simple use of the structure provides estimates on number and species richness at the structure (**Figure 6-92**). Species richness information is useful for comparison to species data collection away from the road, to identify what species are present but may not be approaching the structures.

Figure 6-92: A white-tailed deer photographed moving under a bridge structure in Missouri.



Photographic data analyses require decision rules to consistently interpret photographic data. Below are rules that have been used to evaluate millions of photos in past studies.

1. Define an event from camera trigger to end of the series of photos, or time limit, such as 15 minutes or one hour (Cramer and Hamlin 2019a; Kintsch et al. 2021).
2. Determine the difference between repel and parallel movements (Cramer and Hamlin 2017; Cramer and Hamlin 2019; Dodd et al. 2007; Gagnon et al. 2011).
3. Determine how groups of individuals will be recorded, such as how many were (and were not) successful in the movement through the structure; if the genders and ages of the animals will be recorded (if known), and what genders and age classes were (or were not) successful. This is especially important for rarer species like carnivore mothers with young (Cramer and Hamlin, Cramer and Hamlin 2017; Cramer and Hamlin 2019; Kintsch et al. 2021).
4. Determine whether origin of the direction of travel by individuals is important (record, if so).
5. Determine if the light conditions during events are important to record.

6. Define human events in the rules: how many humans, how long they stayed, and if they had dogs with them. This will allow for a human influence analysis (Gagnon et al. 2011).

6.12.4.2 TELEMETRY DATA

GPS telemetry data can help to determine the effectiveness of wildlife-highway measures at the road interface and at the landscape-level. This data may also be used to assess the effects of traffic on wildlife passage rates and the distribution of wildlife adjacent to the highway (e.g. road-effect zone). Where possible, collect GPS movement data to assess levels of mitigation highway permeability and distribution of locations where animals crossed the road pre- and post-construction; permeability can be compared to determine if any changes occurred along the highway (Gagnon et al. 2013; Gagnon et al. 2014; Gagnon et al. 2017).

Dodd et al. (2007) was one of the first studies to utilize GPS telemetry to determine highway crossing locations of animals, which were inferred from lines connecting consecutive GPS fixes taken every two hours. The locations where the lines crossed the highway in 0.1-mile increments were highlighted. Passage rates and metrics of permeability were determined by comparing the number of times the collared animals approached within 0.15 miles of the highway to the number of times the animal crossed the highway. Dodd et al. (2012) used a BACI approach to evaluate elk adaptation to mitigation along SR-260 in Arizona by comparing passage rates, or proportion of successful crossings to approaches, throughout different phases of construction. This project showed an increase in passage rates as structure density increased. A similar approach was used by Gagnon et al. (2017b) for desert bighorn sheep along US Highway 93 that identified a 1,367 percent increase in passage rates along a newly constructed four-lane divided highway, compared to the previously unmitigated two-lane road.

At the landscape scale, it is important to understand the impacts of roads on movement corridors and the corresponding effectiveness of wildlife crossings. Methods like those used for University of Wyoming's Migration Mapper (2022) that utilize a Brownian bridge movement analysis of GPS collar data and a prioritization based on the number of animals migrating through specific areas can help determine mitigation effectiveness by showing impacts or improvements to movement corridors.

6.12.4.3 STATISTICAL ANALYSES

BACI analysis may be used to compare changes in crash rates between pre- and post-construction in the control sections, with the same crash rate change between pre- and post-construction in the mitigation section (Cramer and Hamlin 2017; Cramer and Hamlin 2019a; Kintsch et al. 2021). An easy mistake is to place the control section at the fence end. This area is not a control, but rather a place to further examine for increased crashes with wildlife moving around the end of the fence and crossing the road. A control area is some distance down the road from the fenced mitigation area, or a nearby similar road, depending on the size of the animals and how far they move. In most situations, BACI studies can be impractical or unattainable because a project may already be completed or sufficient control sites are not available. Where possible, at least one of the comparisons of the mitigation site pre- and post-mitigation (Before-

After), or to sufficient controls (Control-Impact) is the next best option. These analyses are conducted on crash and carcass data.

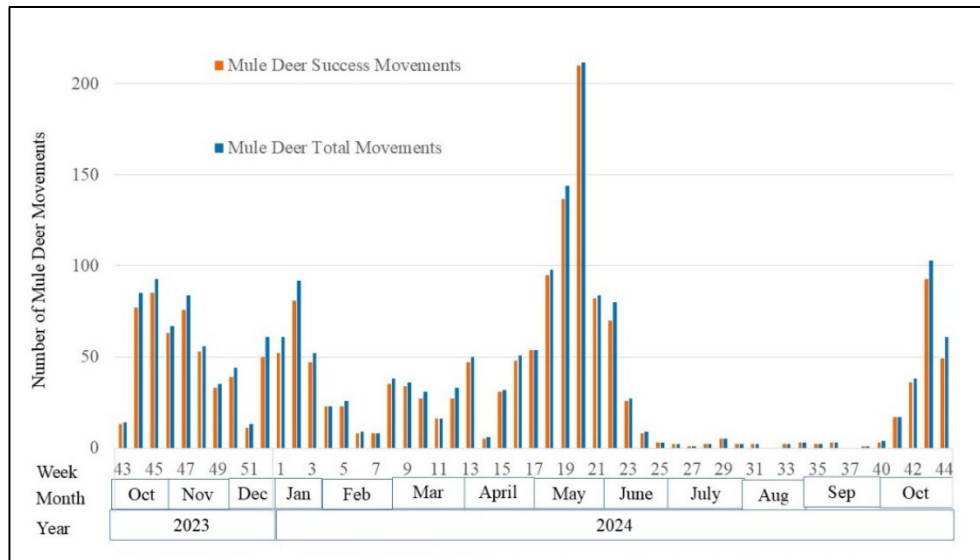
Colorado's US 160 wildlife mitigation project east of Durango provides an example of a straightforward crash data BACI analysis. The project was evaluated for changes in WVC rates in and outside the mitigated area, with the outside control area 0.1 miles from the fence ends (Cramer and Hamlin 2021). The crashes per mile per year were calculated for each section for the pre- and post-construction periods. The changes in rates from pre- to post-construction were then compared for each control section with respect to the mitigation section. Statistical analyses, with either high level statistics such as generalized linear mixed models, or a simple T-test (as was used in this case) can help determine if the changes in crash rates among the controls and mitigation were significant enough to confidently say the mitigation was the cause of the differences. In the Colorado US 160 example, the pre-construction crash rate was different from the post-construction crash rate in the mitigation section ($p = 0.11$); and the crash rate changes between pre- and post-construction in the west and east control sections were different than the crash rate change between pre- and post-construction in the mitigation section (West: $p = 0.12$; East: $p = 0.16$). There was good evidence that the change (decrease) in WVCs in the mitigation section was due to the wildlife crossing structure and fence. These analyses are becoming more common with every wildlife mitigation monitoring project.

Statistical analyses are also conducted on the wildlife use of structures, and preferences for types and dimensions of structures. These analyses are typically carried out with generalized linear models (Cramer and Hamlin 2017; Cramer and Hamlin 2019; Kitsch et al. 2019).

6.12.4.4 REPORTING AND COMMUNICATING

Periodic and final reports for monitoring studies should present various pieces of information important to both ecologists and transportation planners and engineers. Reporting success rates and passage rates is standard in wildlife and transportation monitoring. Researchers should be able to demonstrate the dominant animal use of structures over time. Reporting success rates and the total movements on a weekly or monthly basis helps define how the structure is functioning for the species of interest, as well as the use of the structure over time (**Figure 6-93**).

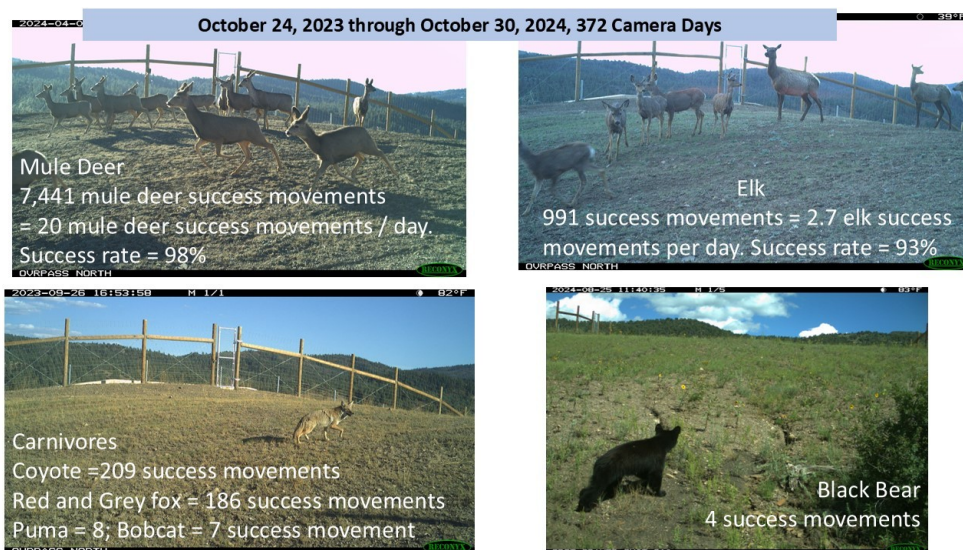
Figure 6-93: Mule deer weekly success and total movements at the US 160 Underpass between October 2023 and October 2024.



Source: Cramer and Hamlin 2025

Successful passages of specific species are measured as the number of times individuals of that species moved through the structure or over an overpass, divided by the number of days of monitoring that structure. A general rule for this rate is that the structure is a success if the equivalent of one successful movement per day occurred. The figure below (**Figure 6-94**) shows a slide of the incredibly successful overpass in Colorado over US 160 at Chimney Rock, with both success rates and successful passages over one year. This figure gives an example of one of the most successful wildlife crossing structures monitored in North America.

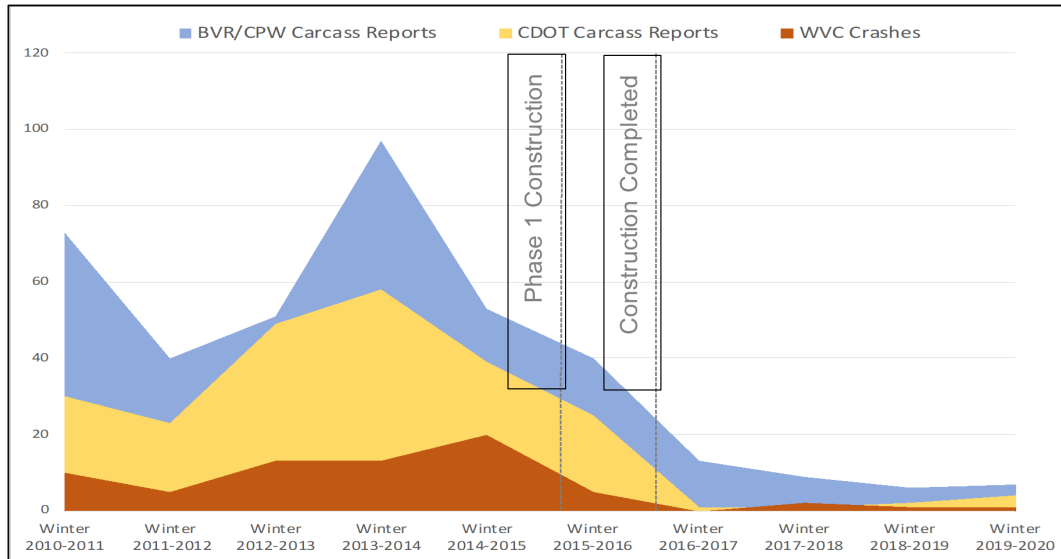
Figure 6-94: Successful movement totals of selected wildlife species across the US 160 Chimney Rock Overpass, October 2023 through October 2024.



Source: Cramer and Hamlin 2025

Reporting on the reduction (or lack of reduction) of WVCs has not always been included in past monitoring studies but is an important part of the evaluation of mitigation projects. An example of a highly successful wildlife mitigation project based on multiple performance measures is the Colorado SH-9 Wildlife Mitigation Project. The graph below was used in multiple media outlets and agency reports to demonstrate how well the fence and seven structures decreased the reported WVCs and carcasses.

Figure 6-95: Colorado SH-9 pre- and post-construction WVC and carcass reports each winter.



Source: Kintsch et al. 2021.

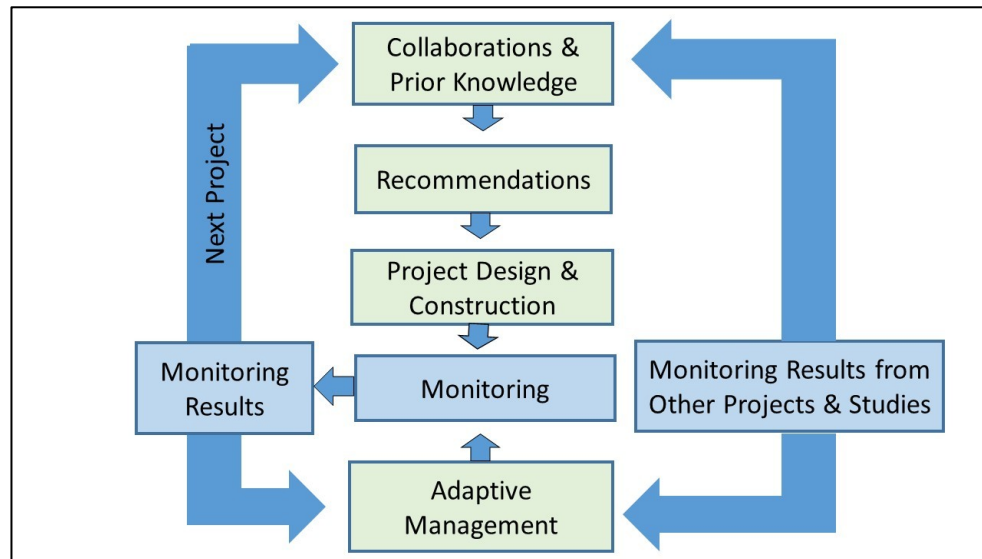
6.12.5 Summary

The effectiveness of the structures in promoting wildlife passage, and the fence and wildlife deterrents in preventing wildlife access to the mitigation road area, are all important to the teams who created and maintain those structures. Monitoring results helps in the adaptive management of all components of the monitored mitigation (**Figure 6-96**). This can mean changes to the substrate in the wildlife crossings structure, removal of barriers near and in the structures, trimming vegetation, placement of additional fence and wildlife crossing structures, adaptations to the deterrents and escape ramps, changes in the timing of human activities (such as nearby hunting) to assist wildlife in their movements, and many other aspects. Monitoring can become a standard part of creating wildlife mitigation. With predetermined performance measures, the monitoring process can help transportation departments meet the letter of a transportation law and thereby help ensure future funding. Monitoring reports may also include an evaluation of the costs and benefits of a mitigation project, which helps in demonstrating how up-front mitigation investments can result in an overall cost savings to society over time (Kintsch et al. 2021). Communicating results in interactive online formats for the public is also important, if there is funding for such endeavors.

Lastly, monitoring reports help wildlife ecologists and transportation professionals create the most cost-effective and ecologically effective wildlife crossing structure that help protect wildlife and the

public from future WVCs. The results of monitoring are part of a circle of adapting the transportation network to make the roads safer, and to provide connectivity for wildlife.

Figure 6-96: Flowchart showing the importance of monitoring in the iterative process of improving WVCs and habitat connectivity mitigation projects. From Cramer et al. 2022b.



Source: Cramer et al. 2022b.

7 Public Involvement

7.1 Webpage

To aid in public involvement efforts for the WVC Study, MoDOT developed a webpage for the Study, accessible through MoDOT's website. The webpage provides information on the Study's goals and timeline, the TAC, and team contact information, as well as answers to frequently asked questions. The webpage also includes links to the Roadkill Observation and Data System (ROaDs) survey, an interactive map showing Study results, and an online form for submitting comments.

7.1.1 Roadkill Observation and Data System (ROaDS)

MoDOT, through a partnership with the Center for Large Landscape Conservation, has provided the public with access to a citizen-science mobile application survey form known as the ROaDS survey. This application was developed by the NPS, USFWS, and Western Transportation Institute at Montana State University to collect standardized WVC data for federal land management agencies.

Once downloaded, the application allows users to mark the location of observed roadkill and/or wildlife crossing the road or near the roadway and input detail such as photos, the type of animal observed, species identification confidence level, the number of animals involved in the incident, the animal status (dead, alive crossing road, and alive next to road), and comments. The application also provides contact information for the WVC Study Team in the event of sensitive



species records and contact information for MoDOT customer service in the event of roadkill posing a safety hazard to motorists.

7.1.2 Interactive Map

As part of the Study, an interactive map was developed to display data analyzed by the Study on wildlife movements and their impact on collisions. The interactive map was made available to the public through the WVC Study webpage on MoDOT's website.

7.1.3 Webpage Comments

Several comments have been received through the webpage comment form. Respondents to the form are asked to provide their closest city, the number of deer they have collided with in a vehicle, and any general comments regarding the Study or WVCs. One received comment was from a reporter with KOMU requesting an interview about the Study. The other two received comments both reported involvement with previous WVCs, and one respondent requested updates on the Study.

7.2 Social Media

MoDOT has also communicated Study information to the public through the use of social media. Informational videos and reels were posted to Facebook, Reddit, and other social media platforms to provide the public with information on why the Study is being conducted. The videos included photos of wildlife crossing roadways and details on WVC statistics. Comments and engagement on the posts were compiled by MoDOT and are discussed below.

Alternatives: many comments from the public included suggestions for wildlife crossing structures, additional signage, and short-term mitigation strategies (such as mowing to improve visibility along roadway ROWs) in both general locations and specific roadways that commenters consider dangerous for motorists and wildlife.

Biological Resources (wetlands, streams, protected species): several comments inquired about specific species to benefit from the WVC Study, including deer, armadillos, and SOCCs.

Cost: several commenters expressed concern about the cost of WVC projects, particularly the impact of cost on taxpayers in Missouri.

Safety (congestion, speeds, adverse travel, conflict points, visibility): the majority of the comments received included concerns regarding safety. Specific roadways or road segments were mentioned as dangerous locations by many of the commenters, both for motorists and wildlife. Other commenters also expressed concern over speeding and cell phone usage as contributing factors to WVCs.

7.3 Fact Sheet

A fact sheet was developed to provide the public and stakeholders with a high-level summary of the Study's goals, methodology, and results. The fact sheet is included in **Appendix J**.

8 Implementation Plan

This section outlines the next steps in implementing the results of the Study and other activities that involve planning for and creating wildlife mitigation and accommodations. This report, and specifically this section, provide MoDOT and partners with details on how to include wildlife considerations in transportation planning, as well as how to plan, fund, design, construct, and maintain wildlife crossing structures and other mitigation.

8.1 Top Implementation Areas - Statewide and by MoDOT District

The results of this Study can be used to aid MoDOT in future transportation planning, construction, daily operations, and maintenance in order to plan for, build, and maintain wildlife mitigation. The Top 10 for this Study were identified based on final scores that included transportation, ecological, and feasibility factors, in addition to a qualitative evaluation of the opportunities to create wildlife mitigation in those areas based on land ownership, land use, and upcoming MoDOT projects, as listed in the 2025 STIP. In order to extrapolate this Study's results into future STIP plans and scenarios, the total quantitative score of each of the Top 10 was used as the final evaluation of the top areas in the state, regardless of upcoming MoDOT projects.

Below, the top priority segments (based on final scores) are presented first by the statewide Top 30 segments (Top 30), then by the Top Five segments (Top Five) for each MoDOT district. These areas can also be viewed in the interactive map discussed in **Section 7.1.2**.

8.1.1 Statewide Implementation - Top 30

The Top 30 are presented in **Figure 8-1** and **Table 8-1**, along with their mean final score (maximum score = 120 points), mean transportation score (maximum score = 50 points), and mean ecological score (maximum score = 50 points) for each location. **Table 8-1** also presents feasibility scores (maximum score = 20 points), mean average reported crashes with wildlife per half mile, and mean percentage of all crashes that were wildlife related. These scores can help MoDOT personnel and their partners better understand why each location was a top area in the modeling.

The mean transportation and ecological scores help to determine if a specific area could potentially qualify for specific funding sources. For example, the Deerfield US 54 segment in the Southwest MoDOT District (Top 30 segment number 7) had the highest mean transportation score of all the Top 30 segments, averaged 2.5 reported crashes with wildlife per half mile per year (equating to five wildlife crashes per mile per year), and 100 percent of all reported crashes were with wildlife. Due to its high transportation score, this Top 30 segment could qualify for highway safety funds from various programs and sources. Likewise, the Wayland-Fox River MO-27 segment in the Northeast MoDOT District (Top 30 number 1) and the Horton Bottoms Natural Area IS-49 segment in the Southwest District (Top 30 segment number 2) had the top two highest scores (respectively) for ecological values. Further evaluation of what wildlife habitats overlap the segments, protected species' presence, the importance of riverine areas within the segments, connectivity values within the landscape, and other ecological evaluations can help identify

potential sources of federal and state wildlife-based funding that may be available to mitigate and protect those locations.

Figure 8-1: Statewide Top 30 Segments Based on Full Quantitative Scores.

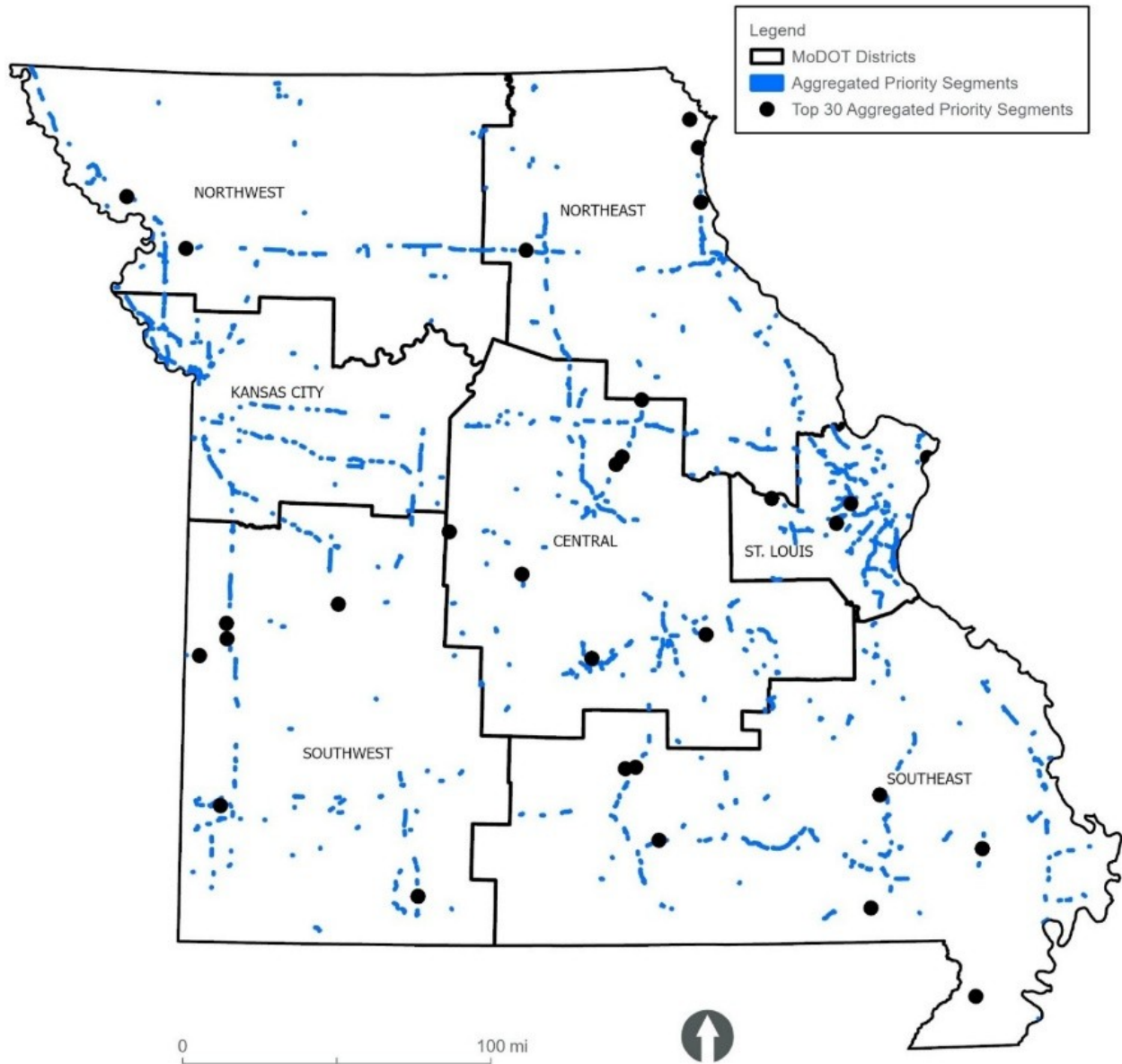




Table 8-1: Statewide Top 30 Segments Based on Full Quantitative Scores, MoDOT District, and Additional Scored Measures.

Final Score Rank	Name ¹	MoDOT District	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴	Mean Feasibility Score ⁵	Mean Annual Average Reported Crashes with Wildlife per Half Mile	Mean Percentage of All Crashes that were Wildlife Related
1	Wayland – Fox River MO-27	NE	71.75	26.00	35.75	10.00	3.34	26.67
2	Horton Bottoms Natural Area IS-49	SW	66.70	14.20	35.83	16.67	1.39	28.10
3	Fairdealing Little Black River Ringo Ford Access US 160	SE	64.46	27.46	23.67	13.33	3.06	44.05
4	Callao-Bevier-Long Branch State Park US 36	NE	63.32	26.01	26.06	11.25	2.19	50.69
5	Meramec State Park MO-8 MP 6-8	Central	62.94	24.38	18.56	20.00	2.29	58.33
6	St. Joseph-Third Fork Platte River US 36	NW	62.59	25.21	27.38	10.00	2.09	31.25
7	Deerfield US 54	SW	62.50	32.50	20.00	10.00	2.50	100
8	St. Louis - Confluence Greenway IS-270 and Riverview Drive	St. Louis	62.07	22.45	27.13	12.50	2.09	36.06



Missouri Statewide Wildlife Vehicle Collision Study Implementation Plan

Final Score Rank	Name ¹	MoDOT District	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴	Mean Feasibility Score ⁵	Mean Annual Average Reported Crashes with Wildlife per Half Mile	Mean Percentage of All Crashes that were Wildlife Related
9	Wildwood Rockwoods Reservation MO-109	St. Louis	61.97	22.85	27.46	11.67	4.17	20.12
10	West of Mountain View Eleven Point River US 60	SE	61.75	30.00	21.75	10.00	2.50	75.00
11	Pacific Meramec River Pacific Palisades Conservation Area RT-F	St. Louis	61.63	17.50	24.13	20.00	1.67	33.33
12	Wakonda State Park US 61	NE	60.74	26.37	24.38	10.00	2.50	38.6
13	Pleasant Valley Center Creek RT-HH	SW	60.50	25.00	25.50	10.00	2.09	29.97
14	Kennett The Floodway Little River Conservation Area US 412	SE	60.14	19.79	22.35	18.00	1.67	21.19
15	Roubidoux Creek Conservation Area MO-17	Central	60.12	17.32	22.80	20.00	1.84	14.88
16	Stover MO-52	Central	60.08	23.33	26.75	10.00	0.83	25.00



Missouri Statewide Wildlife Vehicle Collision Study Implementation Plan

Final Score Rank	Name ¹	MoDOT District	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴	Mean Feasibility Score ⁵	Mean Annual Average Reported Crashes with Wildlife per Half Mile	Mean Percentage of All Crashes that were Wildlife Related
17	Lakeland Little Gravois Creek US 54	Central	59.62	26.12	23.50	10.00	2.78	33.36
18	Piney River Narrows Natural Area Dogs bluff Access MO-17	SE	59.59	13.59	26.00	20.00	2.09	65.00
19	Houston Mineral Springs US 63	SE	59.58	28.33	11.25	20.00	1.67	66.67
20	Auxvasse North US 54	Central	59.51	25.76	23.75	10.00	2.09	36.76
21	Santuzza US 61	NE	59.22	19.22	22.86	17.17	1.79	60.07
22	Osceola Harry Truman Recreation Area MO-13	SW	58.86	21.11	27.75	10.00	1.95	58.33
23	New Bloomfield-Fulton Middle River Mark Twain National Forest US 54	Central	58.84	25.09	23.75	10.00	2.09	30.00
24	Honey Creek Conservation Area IS-29	NW	58.56	29.93	18.63	10.00	4.17	57.64



Missouri Statewide Wildlife Vehicle Collision Study Implementation Plan

Final Score Rank	Name ¹	MoDOT District	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴	Mean Feasibility Score ⁵	Mean Annual Average Reported Crashes with Wildlife per Half Mile	Mean Percentage of All Crashes that were Wildlife Related
25	Dundee Little Boeuf Creek MO-100	St. Louis	58.42	26.67	21.75	10.00	3.34	33.33
26	Douglas Branch Conservation Area IS-49	SW	58.32	14.30	30.03	14.00	1.58	22.14
27	Bloomfield – Aquilla MO-25	SE	58.25	27.50	20.75	10.00	2.50	50.00
28	New Bloomfield-Fulton Middle River Mark Twain National Forest US 54	Central	58.22	25.55	26.00	6.67	2.78	27.69
29	North Branson – Walnut Shade Emory Creek US 65	SW	58.04	24.54	28.50	5.00	2.92	16.25
30	Wappapello Reservoir MO-34	SE	57.87	13.92	23.95	20.00	1.17	47.50

¹ Segment naming convention: Nearest city, natural feature, and/or road.; ² Maximum Score = 120 points; ³ Maximum Score = 50 points; ⁴ Maximum Score = 50 points; ⁵ Maximum Score = 20 points

8.1.2 MoDOT District Implementation – Top Five Segments by MoDOT District

The Top Five segments for each MoDOT district are presented below. This information is intended to help focus efforts by district-level personnel to include actions for protecting and restoring wildlife connectivity and reducing WVCs in upcoming projects, standalone projects, and daily maintenance and operations activities.

8.1.2.1 NORTHWEST DISTRICT

Figure 8-2: Northwest MoDOT District Top Five Segments.

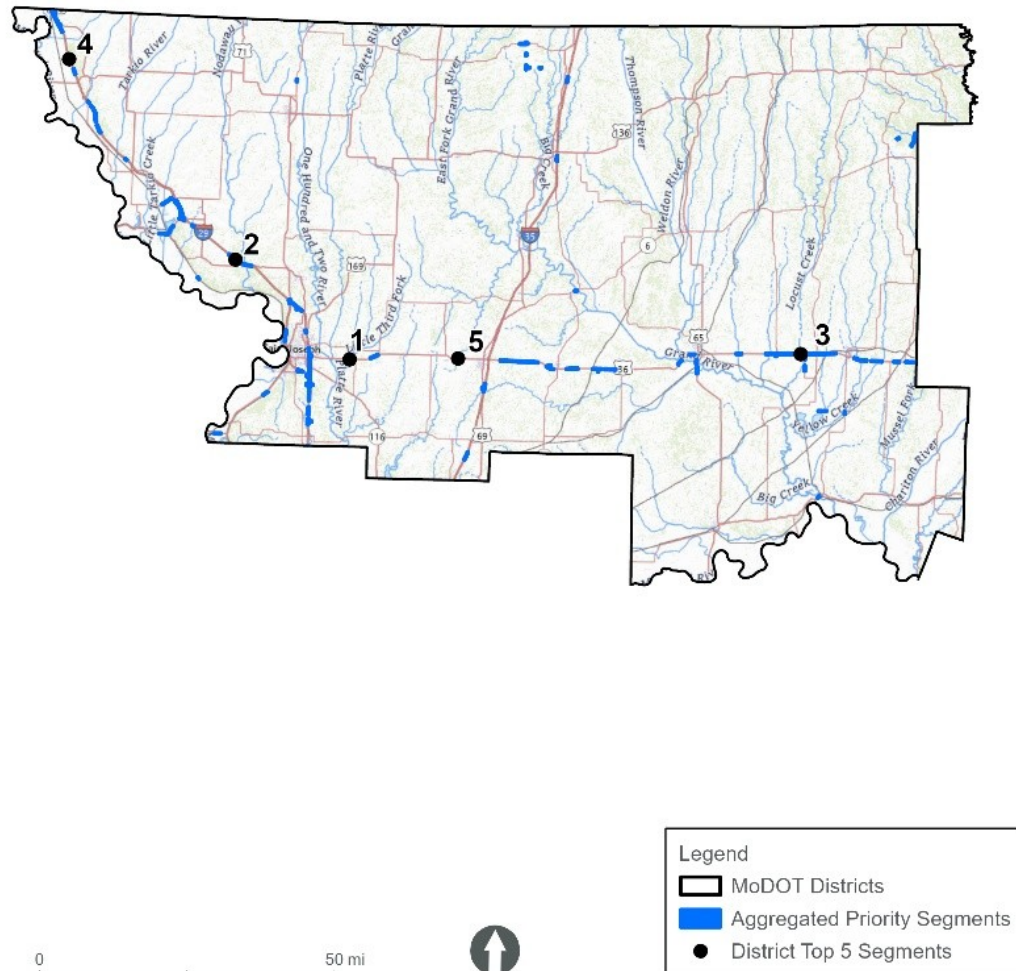




Table 8-2: Northwest MoDOT District Top Five Segments.

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	St. Joseph-Third Fork Platte River US 36	62.59	25.21	27.38
2	Honey Creek Conservation Area IS-29	58.56	29.93	18.63
3	Pershing State Park US 36	56.94	17.91	26.24
4	Rockport-Brickyard Hill Natural Area IS-29	55.40	7.06	31.67
5	Osborn-Grindstone Creek US 36	55.33	24.08	21.25

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.1.2.2 NORTHEAST DISTRICT

Figure 8-3: Northeast MoDOT District Top Five Segments.

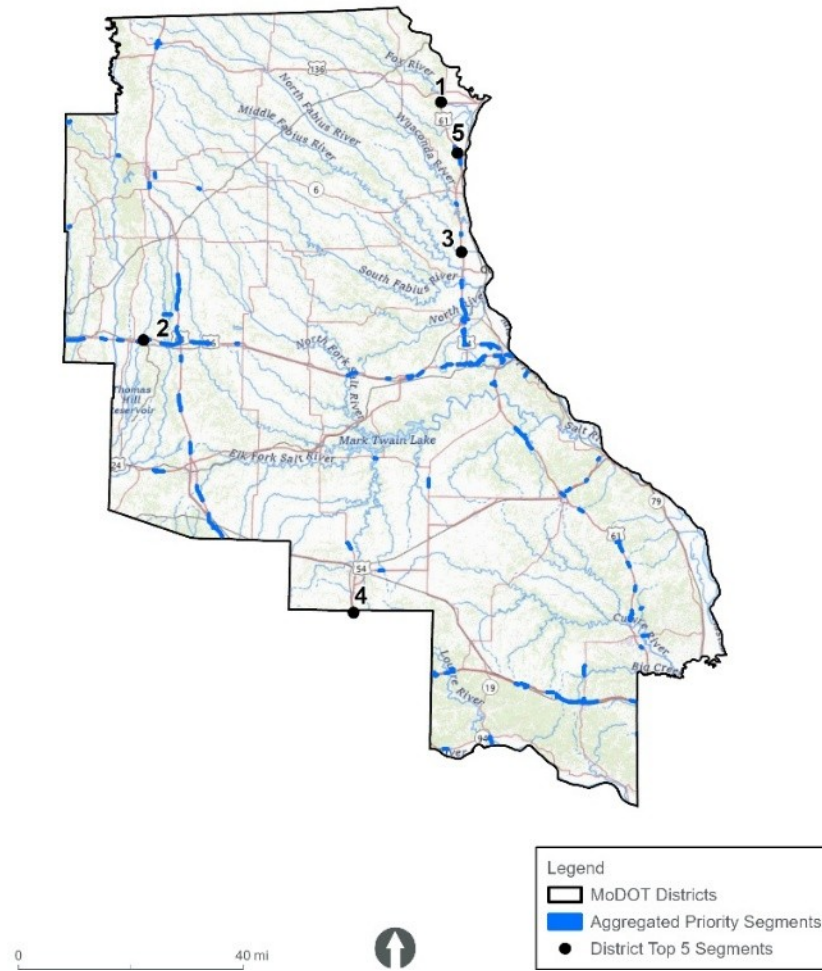


Table 8-3: Northeast MoDOT District Top Five Segments.

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴
1	Wayland - Fox River MO-27 ¹	71.75	26.00	35.75
2	Callao-Bevier-Long Branch State Park US 36	63.32	26.01	26.06

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ²	Mean Transportation Score ³	Mean Ecological Score ⁴
3	La Grange-Wakonda State Park US 61	60.74	26.37	24.38
4	Auxvasse-Jesse Creek US 54	59.51	25.76	23.75
5	Buck and Doe Run Conservation Area US 61	59.22	19.22	22.86

¹ Fox River MO-27 was the number one statewide top scoring priority segment; ² Maximum Score = 120 points; ³ Maximum Score = 50 points; ⁴ Maximum Score = 50 points

8.1.2.3 KANSAS CITY DISTRICT

Figure 8-4: Kansas City MoDOT District Top Five Segments.

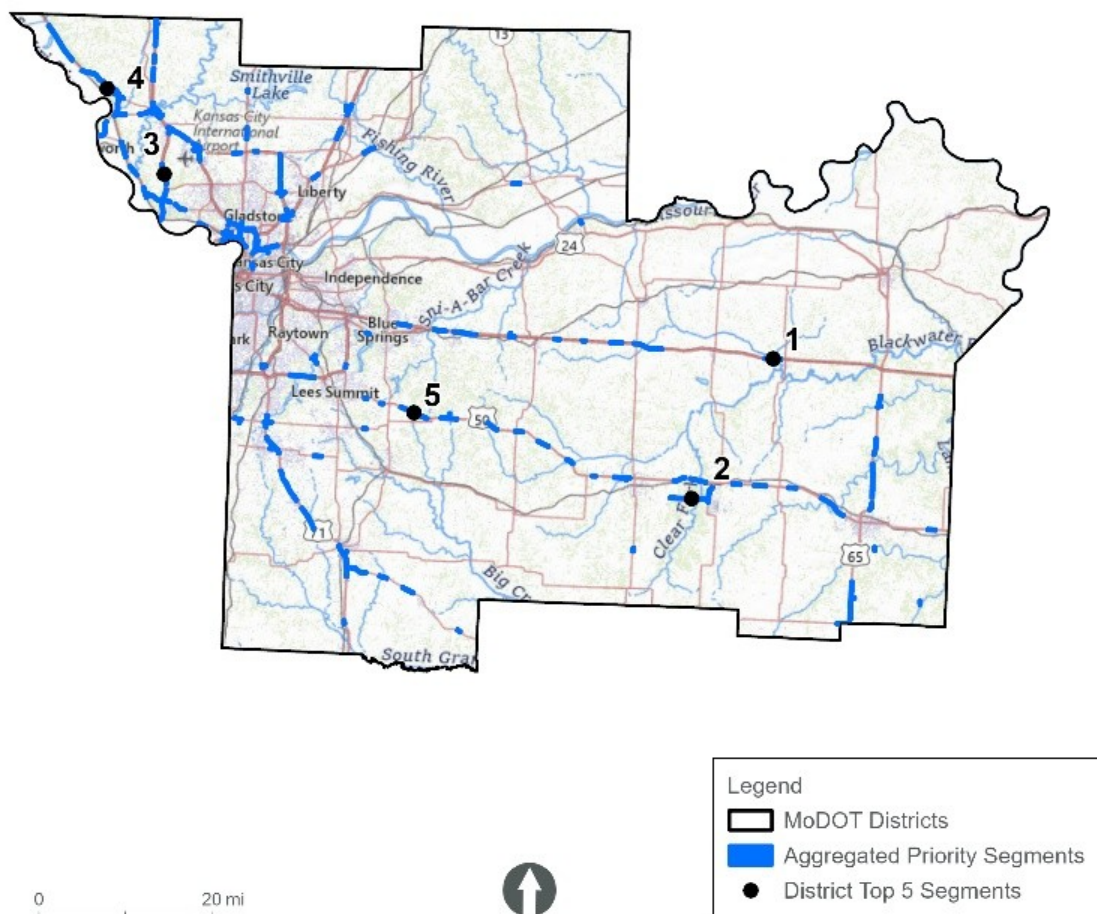


Table 8-4: Kansas City MoDOT District Top Five Segments

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	Sweet Springs – Davis Creek IS-70	56.58	9.79	28.21
2	Whiteman Airforce Base and Knob Noster State Park RT-DD and MO-23	56.57	26.89	13.96
3	Tiffany Springs Park- Kansas City International Airport IS-435	56.39	26.49	19.90
4	Weston Bend State Park MO-273- and MO-45 and NW County Rd JJ	55.67	25.29	21.53
5	Lone Jack Lake Conservation Area US 50	55.47	31.54	16.79

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.1.2.4 CENTRAL DISTRICT

Figure 8-5: Central MoDOT District Top Five Segments.

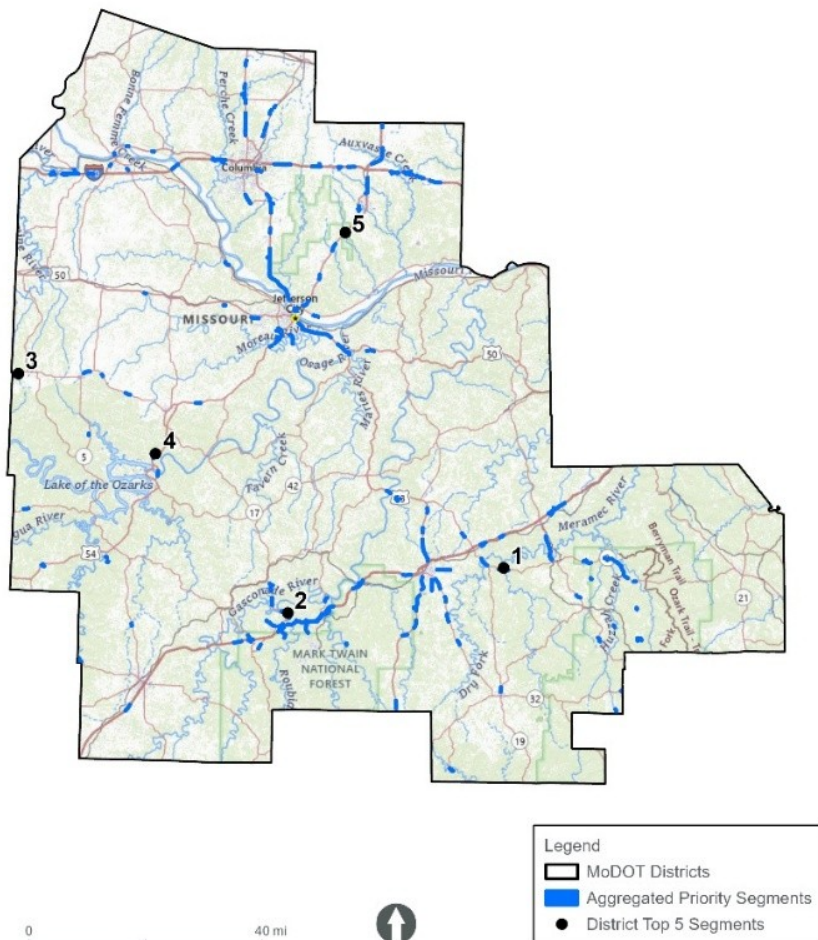


Table 8-5: Central MoDOT District Top Five Segments.

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	Maramec Springs State Park MO-8	62.94	24.38	18.56
2	Roubidoux Creek Conservation Area MO-17	60.12	17.32	22.80
3	Stover MO-52	60.08	23.33	26.75
4	Bagnell Dam Access US 54	59.62	26.12	23.50
5	New Bloomfield-Fulton Middle River Mark Twain National Forest US 54	58.84	25.09	23.75

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.1.2.5 ST. LOUIS DISTRICT

Figure 8-6: St. Louis MoDOT District Top Five Segments.

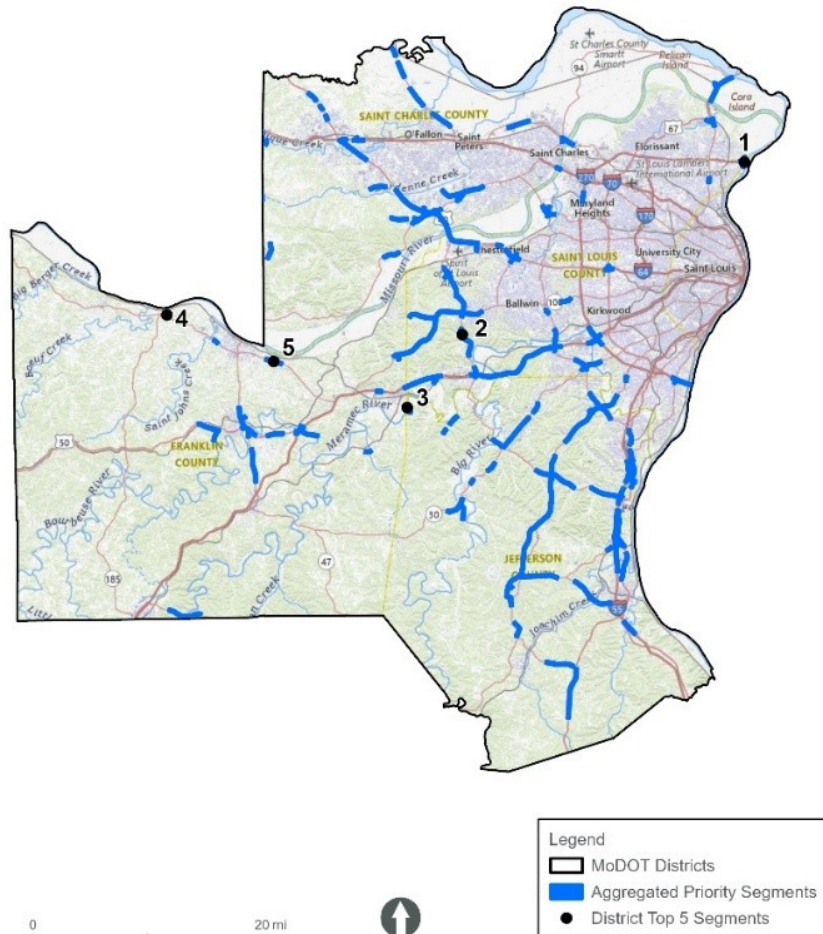


Table 8-6: St. Louis MoDOT District Top Five Segments

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	St. Louis - Confluence Greenway IS-270 and Riverview Drive	62.07	22.45	27.13
2	Wildwood Rockwoods Reservation MO-109	61.97	22.85	27.46
3	Pacific Meramec River Pacific Palisades Conservation Area RT-F	61.63	17.50	24.13
4	Dundee Little Boeuf Creek MO-100	58.42	26.67	21.75
5	Washington Dubois Creek MO-100	57.47	26.47	21.00

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.1.2.6 SOUTHWEST DISTRICT

Figure 8-7: Southwest MoDOT District Top Five Segments.

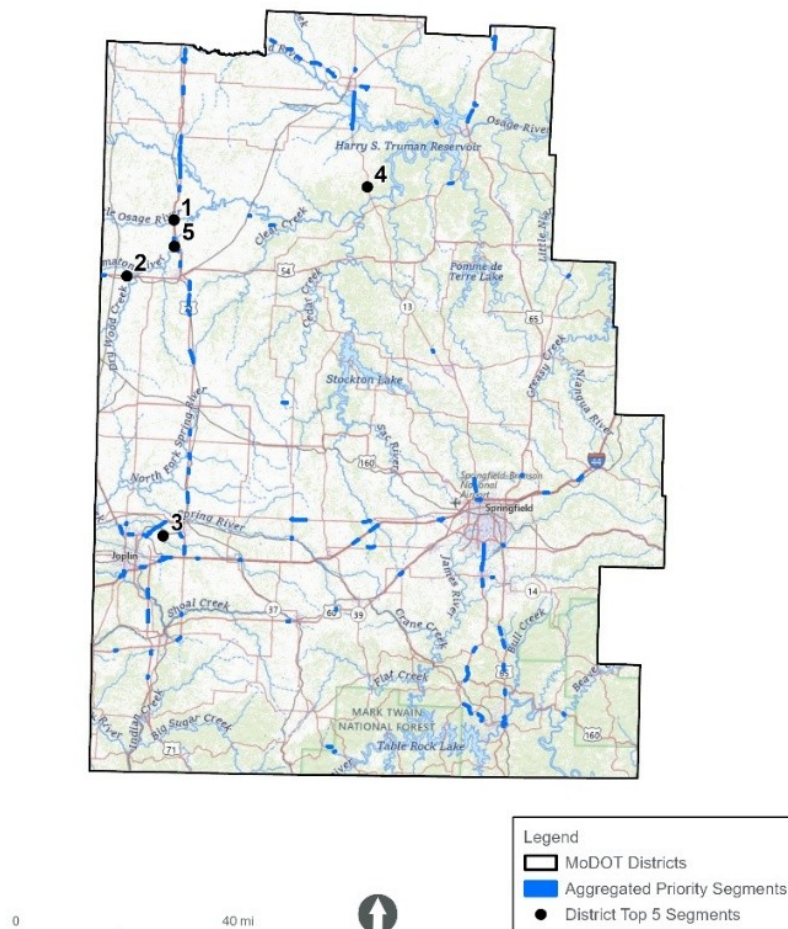


Table 8-7: Southwest MoDOT District Top Five Segments

Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	Horton Bottoms Natural Area IS-49	66.70	14.20	35.83
2	Deerfield US 54	62.50	32.50	20.00
3	Pleasant Valley Center Creek RT-HH	60.50	25.00	25.50
4	Osceola Harry Truman Recreation Area MO-13	58.86	21.11	27.75
5	Washington Douglas Branch Conservation Area IS-49	58.32	14.30	30.03

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.1.2.7 SOUTHEAST DISTRICT

Figure 8-8: Southeast MoDOT District Top Five Segments.

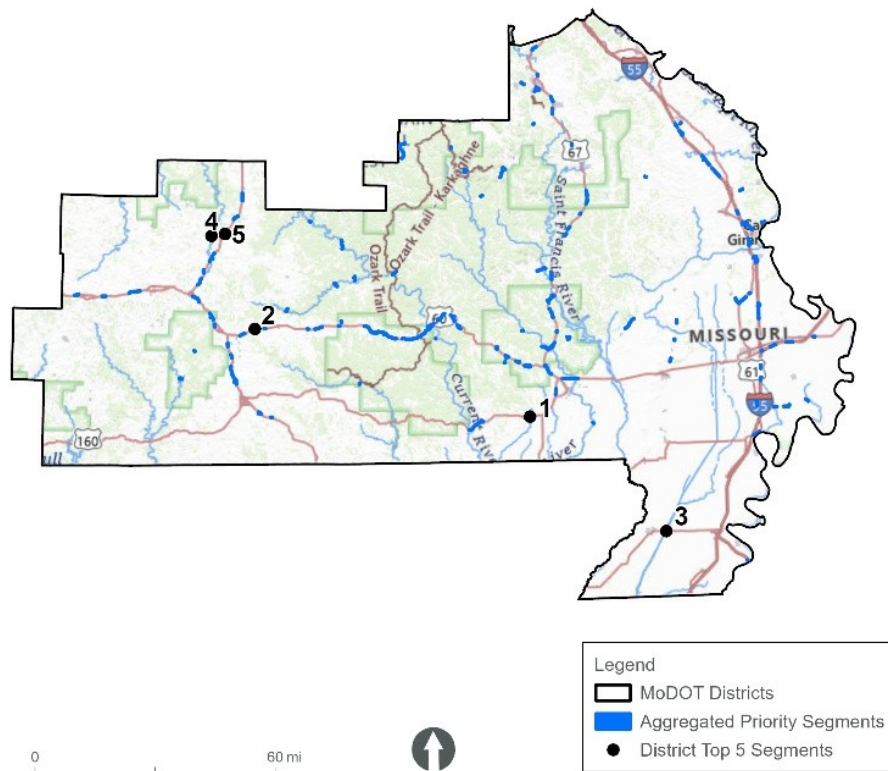


Table 8-8: Southeast MoDOT District Top Five Segments

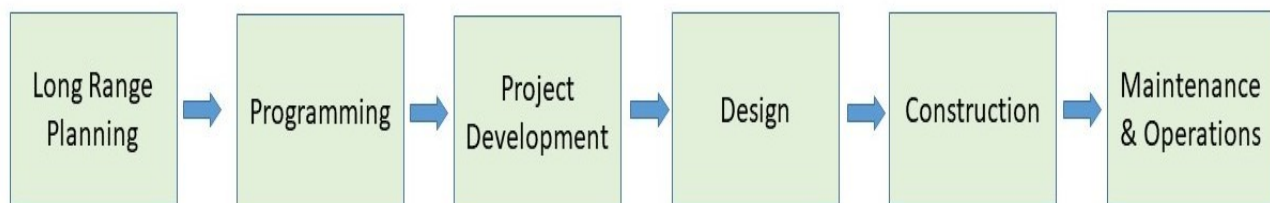
Rank	Top Locations for All Factors Based on Final Score	Mean Final Score ¹	Mean Transportation Score ²	Mean Ecological Score ³
1	Fair Dealing Little Black River Ringo Ford Access US 160	64.46	27.46	23.67
2	West of Mountain View Eleven Point River US 60	61.75	30.00	21.75
3	Kennett The Floodway Little River Conservation Area US 412	60.14	19.79	22.35
4	Piney River Narrows Natural Area Dogs bluff Access MO-17	59.59	13.59	26.00
5	Houston Mineral Springs US 63	59.58	28.33	11.25

¹ Maximum Score = 120 points; ² Maximum Score = 50 points; ³ Maximum Score = 50 points

8.2 Optimization of Wildlife Considerations in Transportation Processes

MoDOT's mission statement includes the goal of providing a safe transportation system, which will necessitate the consideration of wildlife in the transportation planning process to help meet that mission by reducing WVCs. Just as the collaborative approach of Context Sensitive Solutions began changing the way transportation systems consider surrounding communities and the environment for the past 25 years, the new "normal" of considering WVCs and wildlife connectivity in all phases of the transportation process will help change and shape the way MoDOT creates a "functional and safe transportation system that also supports local character and environmental sustainability," as the Context Sensitive Solutions approach does (Center for Environmental Excellence 2025). The transportation process of long-range planning to daily operations can be characterized by the six steps outlined below (**Figure 8-9**). Each step is briefly presented and action items on possible modifications and additions are included.

Figure 8-9: The standard transportation planning process.



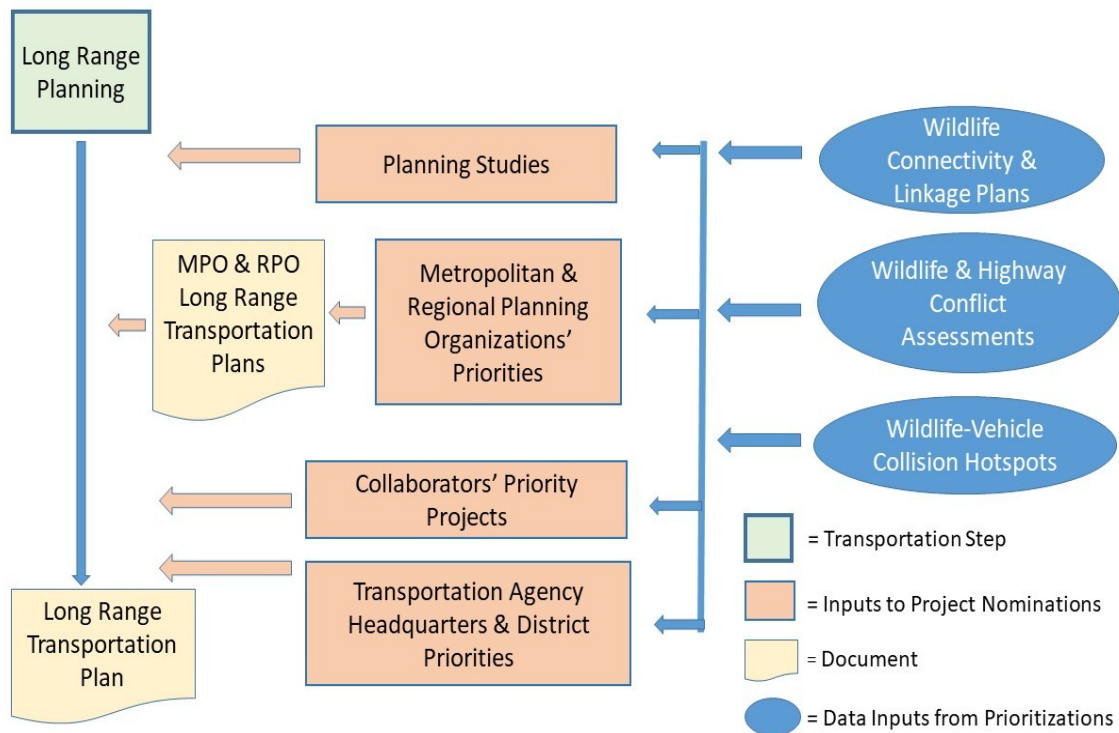
Source: Cramer et al. 2022a.

8.2.1 Long Range Transportation Planning

Long-range transportation plans are a result of many other plans, studies, reports, data, and relationship building among personnel in Metropolitan and Regional Planning Organizations (MPOs and RPOs), the DOT, and partner agencies (**Figure 8-10**). The plans define an

overarching vision for the future of a transportation system, establish goals and objectives, and guide the selection of transportation policies, programs, and projects to meet those goals over a 20-year time frame (Waldheim et al. 2015) (**Figure 8-10**).

Figure 8-10: The range of inputs into a DOT long-range transportation plan that includes wildlife considerations.



Source: Cramer et al. 2022a

MoDOT provides a detailed framework for transportation decision-making in their Engineering Policy Guide (EPG) (MoDOT 2025a) and is in the process of updating its Long-Range Transportation Plan (LRTP) through 2026 (MoDOT 2025l). An important entry point into the LRTP is to provide information that identifies needs along with supporting data. The following action items are recommendations for how wildlife considerations can be included in the LRTP as it is being developed and finalized.

8.2.1.1 ACTION ITEMS

Include MoDOT District-Level Input into Long Range Transportation Plans

Recommendation: MoDOT district champions of potential wildlife mitigation and accommodation projects or parts of projects will need to advocate for inclusion of those projects into the LRTP.

The MoDOT transportation needs to be included in the LRTP are prioritized in each MoDOT district. MoDOT Headquarters and district environmental staff will need to work with district planning staff to advocate for inclusion of WVC data and habitat connectivity goals in the LRTP update process. The crash data and other information from this Study regarding the top wildlife-



vehicle conflict priority areas can be brought into the LRTP development process in early 2026 and at later LRTP developments. It is important to identify and define corridor or roadway-specific problems and improvement needs. The top 10 prioritized projects from this Study were detailed enough to bring any of them to the LRTP with data and solutions that could be incorporated into the LRTP. The district champions will bring forward these projects that include some accommodation for wildlife for inclusion and prioritization in the LRTP.

Inform Metropolitan Planning Organizations' Transportation Planning

Recommendation: District environmental and planning staff work with MPOs and RPOs to identify top wildlife-vehicle conflict areas within their jurisdiction and include mitigating those areas in transportation plans, which are then included in the LRTP.

MPOs and RPOs have collaborative planning processes that result in localized transportation plans. In turn, those MPOs and RPOs work collaboratively with MoDOT's district offices to prioritize future transportation needs in those plans, which are then incorporated into the LRTP (MoDOT 2025a). MoDOT personnel will need to work with MoDOT district planners to contact local representatives of MPOs and RPOs to identify areas of wildlife-vehicle conflict and WVCs within their districts that can be used to indicate where there are mitigation needs for inclusion in their plans. This collaboration will include providing critical data analyses, maps, and recommendations for mitigation solutions that can inform the MPO and RPO transportation plans. The results of this WVC Study, among many objectives, were developed to inform these plans.

Add Top Wildlife-Vehicle Conflict Projects to the Missouri High-Priority Unfunded Needs List

Recommendation: MoDOT staff should work to include WVC mitigation needs to the Missouri High-Priority Unfunded Needs List.

The High-Priority Unfunded Needs List has three tiers of needs that are put forth for future consideration. Tier One includes projects that could be accomplished within the five-year STIP. Tiers Two and Three include project needs beyond the STIP five-year time frame. This list of unfunded needs provides direction for future years' STIP development (MoDOT 2025n). It is important that environmental and traffic safety MoDOT staff get WVC mitigation needs added to the Missouri High-Priority Unfunded Needs List. MoDOT environmental staff or an outside consultant would need to help with the cost estimates for WVC mitigation needs for the high priority areas.

Integrate WVC Information into Missouri's Strategic Highway Safety Plan

Recommendation: Integrate WVC planning and mitigation for each Missouri Strategic Highway Safety Plan.

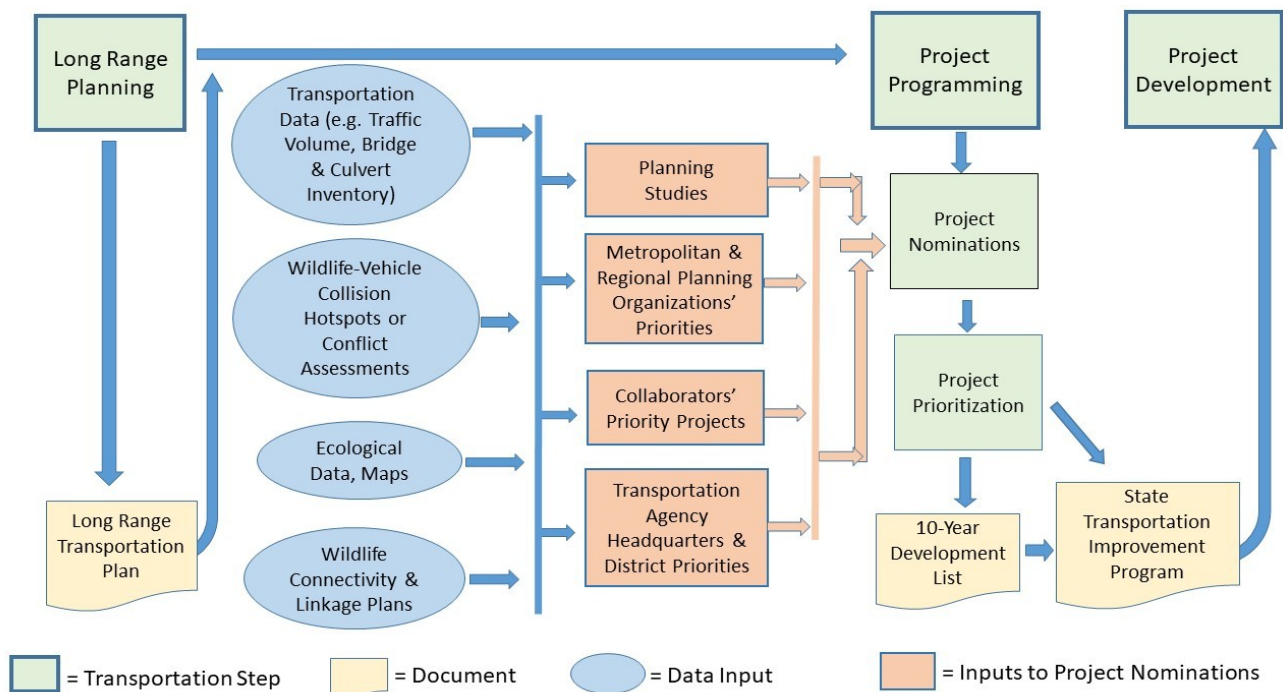
Missouri's Strategic Highway Safety Plan establishes statewide safety goals and guidelines for using safety funds and is intended to be used by all traffic safety advocates in their respective communities (MoDOT 2025a). There is an upcoming possibility to integrate WVC planning and mitigation for the 2026-2030 Missouri Strategic Highway Safety Plan, and certainly future opportunities to provide input to Strategic Highway Safety Plans afterward. Environmental staff will need to continually inform highway safety and traffic staff of the data, maps, and results of this Study, and petition for this integration so that WVCs are considered a funding-worthy factor

in project nominations. Traffic safety engineers are important allies to help elevate priority segments with higher WVC rates to projects using safety funds.

8.2.2 Programming

Programming is the process DOT's use to select projects that will be put forth for funding in the STIP. This is an extremely important part of the process for creating standalone wildlife mitigation projects. It is also important for the MoDOT environmental staff to negotiate wildlife accommodation within transportation projects that are moving through this process, if wildlife-vehicle conflict is a concern within or near these projects. Information from the LRTP plus data, maps, plans and studies, and collaborator, district, and headquarters staff priorities are brought together in project programming and ranked for nomination to move to the STIP (**Figure 8-11**).

Figure 8-11: The LRTP, Programming, and Project Development steps of the transportation planning process.



Source: Cramer et al. 2022a.

8.2.2.1 ACTION ITEMS

Determine if the Project Is Within or Outside of the Priority Segments

Recommendation: The maps developed in this Study should be loaded into the TMS and a step should be added to the Programming process with instructions for users to determine if the potential project overlaps with priority segments.

MoDOT's TMS is used to visualize a multitude of transportation data such as traffic volume, crashes, environmental compliance, and infrastructure during the transportation planning process. The resulting maps from this Study show all the reported wildlife-vehicle crash hot spots, and the priority segments should be uploaded to the TMS for review when the programming process is conducted. The programming process for headquarters and districts should contain a

step that determines overlap with priority segments. If the project is not within a hot spot or priority segment, the process is conducted as usual. If the project is in or adjacent to one of the priority segments, however, the planning process should contain instructions for consultation with MoDOT environmental staff to determine wildlife concerns in the area. Environmental staff could then conduct steps presented in the Project Development process (discussed below).

Continue to Gain Support for Wildlife Mitigation Projects Through Programming

Recommendation: Advocate for specific wildlife mitigation projects or for the inclusion of wildlife mitigation within other projects. Continue to rally support for the project and guide its proposal through the programming process until it is on the STIP.

The STIP process is carried out each year. Advocates for a specific project need to champion and usher the project through the programming process until it is on a specific STIP. Once a project is added to MoDOT's STIP, it has funding commitments and (barring unforeseen circumstances) will be delivered. To gain support, wildlife mitigation champions will need to use the reported wildlife-vehicle crash hot spot maps, the priority segment maps, the rankings of those segments, and the data contained in the transportation and ecological scoring of those segments to help secure funding. The benefit-cost analysis from the Study for the Top 10 segments can be used to help demonstrate cost effectiveness. Potential funding resources are presented in **Section 8.3** below.

Plan Collaboratively with Partners

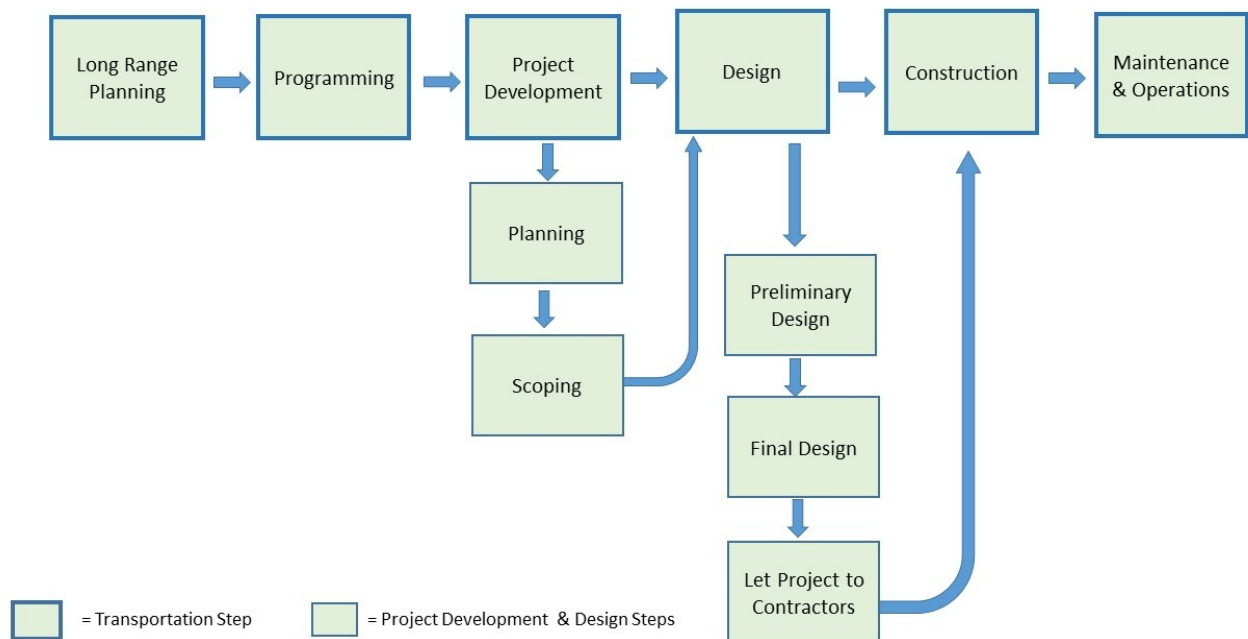
Recommendation: MoDOT wildlife champions should be partnering with MDC and other partners to bring data, resources, and influence to the project development process.

Wildlife concerns can be brought into potential projects as standalone projects or part of other transportation projects. MDC plays a critical role in bringing data, funding, and planning coordination to the programming step that decides what projects progress to the STIP. The collaborative partnership between MoDOT and MDC has already been established and can be institutionalized through several actions mentioned below in the Collaboration section. MDC can bring funding commitments to the process and lend leverage to championing specific projects.

8.2.3 Project Development

Once a project has been named in the STIP, it moves to the project development step (**Figure 8-12**), which creates the framework for a project, its schedule, milestones, and cost estimate. MoDOT has outlined their specific project development chronology on its webpage (MoDOT 2025c).

Figure 8-12: The Project Development to Construction steps in the transportation planning process.



8.2.3.1 ACTION ITEMS

Add a section to the RES form to evaluate if the potential project is in a priority segment or WVC Hot Spot

Recommendation: Add a secondary checkpoint to the planning process by including a project location check with respect to wildlife-vehicle conflict and wildlife crash priority locations to the RES.

With the addition of this section in the RES form, a second mechanism is created to ensure engineers and planners are considering if wildlife mitigation measures need to be included in the transportation project.

Include WVC Concerns into the Safety Assessment for Every Roadway (SAFER) Document

Recommendation: There should be an entry in the Safety Assessment for Every Roadway (SAFER) document where project managers evaluate WVC concerns.

SAFER is a safety analysis tool used to facilitate a discussion of safety in all MoDOT projects, regardless of the project's original purpose and need. Project Managers should use the SAFER document during the development of transportation projects (MoDOT 2025p) to consider baseline safety improvements to the project. The SAFER tool uses thought-provoking questions based on project type to facilitate safety discussions beyond standard project crash history analysis. The tool's questions to consider in project development are organized under the following categories: Vulnerable Roadway Users; Access Management; Roadway Visibility; Roadway Alignment; Roadway Surface; Intersection/Interchange Design; Roadside; Transportation Systems



Management and Operations; and other considerations. MoDOT staff with knowledge of WVCs and the results of this Study could find ways to integrate WVCs into one or more of those above listed categories to bring the issue of WVCs into the discussion and consideration of all MoDOT projects.

NEPA Reviews Should Include Wildlife-Vehicle Conflict Screening

Recommendation: Early in the scoping process, integrate WVCs, wildlife conflict screening, and recommendations into NEPA and MoDOT's environmental studies process.

MoDOT Environmental staff recently created a WVC project screening basemap to share with the MoDOT Environmental Group. This map, plus the priority segments, WVC crash hot spot map, and species habitat maps can be used to help staff estimate the specific improvements (size, location and extent) that can be added to a project to accommodate wildlife. The specific steps for developing these recommendations are:

- Determine the root causes of the wildlife and transportation problem, issue, or concern, using this Study as a resource along with other data, maps, studies, and reports.
- Review the social, historical, economic, energy, environmental and other pertinent impacts.
- Develop a range of possible improvements.
- Evaluate, estimate, and choose the preferred improvement.
- Set the improvement's physical limits.
- Accurately estimate the preferred improvement's cost for programming, and
- Forecast the improvement's delivery schedule.

8.2.4 Design

There are four stages to transportation project design: location/conceptual, preliminary plans, ROW, and final design. There are also opportunities to add retrofits to existing structures that would make them more wildlife friendly or guide wildlife to these structures. There are three suggested approaches to help inform this step that should all be developed within MoDOT:

1. Refer to national level manuals and guidebooks in the absence of Missouri-specific guidelines and refer to this Study for site-specific design recommendations for the top 10 Priority Areas.
2. Update the EPG, and
3. Create a Best Management Practices (BMP) Manual.

8.2.4.1 ACTION ITEMS

Consult This Study, FHWA, and Other Design Guidelines If Wildlife Mitigation and Accommodation Components Are Needed for a Project

Recommendation: Incorporate the best practices for the species of concern, budget, and location based on FHWA guides, other guides, and this Study's Top 10 segment recommendations.

This Study includes the specific design recommendations for the Top 10 segments of greatest concern and urgency for MoDOT to address WVC challenges and wildlife connectivity (see **Section 6**). If a project is outside of these 10 locations, the MoDOT environmental staff will have to first refer to **Section 3.1** in this Study to best understand the general types of wildlife



accommodations possible. Secondly, staff will need to confer with several national-level guidance manuals to get a better sense of what design specifics would work best for the species at hand and the situation. These manuals include but are not limited to:

- The Federal Highways and Nevada Department of Transportation Pooled Fund Study Manuals:
 - The Animal Vehicle Collision Reduction and Habitat Connectivity Pooled Fund Literature Review (Huijser et al. 2022).
 - The Strategic Integration of Wildlife Mitigation into Transportation Procedures: A Manual for Agencies and Partners (Cramer et al. 2022a).
- Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario (Gunson et al. 2016).

In 2027, a National Cooperative Highway Research Program study titled “Practices for Wildlife Passage and Habitat Connectivity” will be completed that will update the 2011 FHWA Guidebook: Wildlife Crossing Structure Handbook Design and Evaluation in North America (Clevenger and Huijser 2011). The 2027 publication will be a guide to planning, design, construction, maintenance, and monitoring wildlife infrastructure (Transportation Research Board 2025).

Update MoDOT EPG with Standards for Wildlife Mitigation Components

Recommendation: Several categories of designs within the MoDOT EPG could be updated with wildlife friendly designs and specific wildlife infrastructure designs. These categories include:

Category 606 Guardrail and Guard Cable (MoDOT 2025d): Add a section on how guard cable is a more wildlife-friendly design as opposed to guard rails.

Guard cables are the preferred design of a guard to keep vehicles from leaving travel lanes in areas where deer and other wildlife may be moving across the road. Guard rails, and especially concrete barriers, are obstacles to wildlife and have a tendency to trap wildlife on the road. Box beam rails are a second choice for guards if cables are not chosen.

Category 607 Fencing (MoDOT 2025e): Add a section giving specifics on designs of different types of wildlife fencing.

Wildlife exclusion fencing is designed and installed a bit differently than typical ROW fences. For example, there should be no barbed wire guide wires anywhere on the fence. Engineers in the design process, both in MoDOT and outside consultants, need standard plans or designed exemption plans for these features. The MoDOT WVC page, future BMP Manual (discussed below), and the outside guidance manuals listed above could provide guidance for fencing design and installation.

Category 611 Embankment Protection (MoDOT 2025f): Add a section to all articles within the Embankment Protection to provide a 3 to 12-foot pathway (also known as wildlife passage benches) in the rock and other rip rap for wildlife and human movement beneath bridges. Also add a section on riprap filler material and riprap surface treatment, which can be taken from Minnesota guidelines (Leete 2014).



Include links to other states' guidance documents or create MoDOT's own guidance documents, using North Carolina, Virginia, Wisconsin, Minnesota, and other DOT's guidance/plans. Include definitions and links to the statewide study webpage and a link to the TMS mapper with WVC hotspot data, stating it is required for all projects with a mapped WVC hotspot. Work with the environmental contact for the specific MoDOT district or statewide WVC contact, or provide a "contact WVC Team" email address.

Category 640 Pavement and Median Drainage (MoDOT 2025g): Add a section to instruct the design of drainage structures to empty water away from the entrances of designated wildlife pathways beneath bridges and at culvert entrances.

Category 700 Structures and Hydraulics (MoDOT 2025h): In the Structures and Hydraulics guide, find specific places to insert wildlife crossing structures, wildlife shelving, escape ramps, and in-road deterrents, such as double cattle guards, and add design specifics to any of the following: 724 Pipe Culverts; 725 Metal Pipe and Pipe-Arch Culverts; 727 Structural Plate Pipe and Structural Plate Pipe-Arch Culverts; 733 Precast Concrete Box Culverts; and 751 LRFD Bridge Design Guidelines.

Category 127.16 Wetland and Stream Mitigation (MoDOT 2025b): Create a similar category and page for Wildlife Mitigation with instructions for Design, Construction, Maintenance, and Monitoring.

Create a Missouri BMP Manual for Mitigating Roads for Wildlife

Recommendation: MoDOT should create a BMP Manual for designs of all types of wildlife mitigation and their Missouri target species.

MoDOT should develop a set of BMPs and guidelines for reducing WVCs while promoting wildlife connectivity across or under roads. This should be a formally developed set of guidelines that would be useful to planning and engineering design teams by detailing the different mitigation infrastructure, where that infrastructure could work, where it should and should not be used, the pros and cons of each type of infrastructure, and importantly, what types of infrastructure work with what types of species. This Study could provide the base for the BMP manual.

8.2.5 Construction

There are two areas of concern for construction of all transportation projects and for the construction of wildlife crossing structures and other mitigation: ecological concerns written into contracts, construction impacts, and off-site considerations. The BMPs have detailed specifications to include in construction plans as to how to create specific features and avoid impacts. Construction activities should be monitored weekly or at least monthly by MoDOT environmental staff and collaborative partners in MDC to assist contractors with adherence to design specifications and construction contract details.



8.2.5.1 ACTION ITEMS

Ecological Concerns in All Transportation Projects Should be Written into Construction Contract Requirements

Recommendation: All transportation projects should have requirements for construction to avoid, minimize, and mitigate construction activity impacts to wildlife.

Include wildlife mitigation elements in construction contracts. This includes all transportation projects in areas where wildlife are present, regardless of wildlife mitigation infrastructure. The following considerations will need to be codified in contracts to ensure activities avoid, minimize, and mitigate impacts to wildlife and habitat (Cramer et al. 2022a).

- Waterway areas should be avoided during periods of high flow to minimize impacts to fish and wildlife and their habitat.
- Minimize the length of disturbance along natural waterways.
- When construction is complete, remove temporary fills, structures, debris, and other materials.
- Plastic erosion netting is explicitly to be avoided, as wildlife can become entangled and die in plastic erosion netting. Natural fiber erosion control alternatives are encouraged in lieu of plastic.
- Make certain to include provisions that the construction is completed or halted for the season prior to wildlife special needs for movement, breeding, hatching, and other factors where wildlife species are sensitive to construction activities.
- Create fencing and exclusion zones to protect specific species, such as the Blanding's turtle.
- Make certain construction activities adhere to wildlife infrastructure designs, such as no barbed wire on wildlife exclusion fences, no blocking of existing culverts with wildlife exclusion fences, fence materials are to be installed down to the ground with no openings to allow animal passage, and protection of native vegetation.
- The contract should include the timing of meeting with project biologists in MoDOT to ensure any changes and incorrect construction are rectified and any challenges are addressed.

Minimize Site Impacts of Construction Activities

Recommendation: The environmental impacts of off-site construction activities should be written into the construction contract.

Environmental documents for construction impacts of road projects often do not take into account many off-site activities and land disturbance that are necessary for road construction. The larger impacts of construction activities must be identified and be a part of the planning process for construction projects that have the least impact on the natural environment (Cramer et al. 2022b).

Most, if not all, of the following seven items are necessary for any construction project implementation, not just for wildlife related projects. These concerns need to become part of the construction contract and NEPA planning documents well before the project has begun.

The seven off-site construction impacts to consider include:

1. Borrow and waste sites, material balance – look for alternate borrow or waste sites outside the immediate project limits and preserve an area for topsoil and soils embedded with native seed.

2. Contractor use/staging areas need to be identified and minimize placement outside of the ROW, or the contractor rehabilitates the area afterward.
3. Water for construction needs to be planned for in storage areas nearby.
4. Contractor access and detours need to be carefully considered so there are limitations to additional unnecessary disturbance. Likewise, provisions should be made for any remaining disturbance or impacts from previous projects.
5. Geotechnical investigation access will need to be restricted to where subsurface investigations for design parameters can occur to help save existing vegetation that may be critical wildlife habitat.
6. Preparing for relocation of utilities and their impacts is necessary to minimize the footprint and location of the disturbance.
7. Document required mitigation of impacts either in the original NEPA document with identification of locations or add the costs to a pre-approved mitigation banking program for the project.

8.2.6 Maintenance and Operations

Maintenance personnel are critical to the daily operations and maintenance of the road and wildlife mitigation infrastructure, yet their role is often overlooked. Maintenance personnel will need to be brought into the planning process from the long-range transportation plans all the way through the construction contracts. When new structures, fences, and other wildlife accommodations are placed, they most likely do not come with additional funding for the care and maintenance of those components of the roadway. It is important that the full arc of the transportation process include maintenance personnel considerations.

8.2.6.1 ACTION ITEMS

Demonstrate to Maintenance Personnel the Importance of Carcass Reporting

Recommendation: MoDOT environmental, planning, and traffic safety staff should be in regular communication with on-the-ground MoDOT maintenance groups as to the importance of carcass reporting, the results of how the data was effectively used, and how reductions in collisions with wildlife mean a safer work environment for staff.

Include Maintenance Staff in Mitigation Infrastructure Planning

Recommendation: Maintenance representatives should be at the table from the beginning in long-range transportation planning through construction to help explain and monetize the challenges and care that come with wildlife mitigation and accommodation.

Maintenance of Wildlife Crossing Structures and Existing Structures for Wildlife Use

Recommendation: Maintenance personnel will need to check wildlife exclusion fences for holes and repair, clear debris from culverts and beneath bridges, report problems with ice and snow buildup, trim vegetation beneath bridges and at culvert entrances, and report any increases in carcasses in areas that have been mitigated.

8.2.7 Research

Research or monitoring of wildlife mitigation, and the impacts of roads, traffic, and road construction on wildlife are important components of the full cycle of the transportation process

(see **Figure 6-96**). The information learned from research helps to adaptively manage specific wildlife mitigation infrastructure and inform future projects. The research, including data collection, mapping, and modeling involved with wildlife crash and carcass data, helps to inform and bring wildlife concerns into the transportation process.

8.2.7.1 ACTION ITEMS

Scientifically Monitor Existing and New Structures for Wildlife Use

Recommendation: Monitor all new wildlife infrastructure using protocols MoDOT will develop from referencing recommended strategies for monitoring mitigation from Section 6 of this Study, that are then integrated into MoDOT's asset management system.

Standardize GIS Mapping of Wildlife Locations and Habitat

Recommendation: GIS mapping procedures by natural resources agencies and academics should incorporate accurate, field-based data on wildlife locations, habitats, and movement patterns in relation to roads. These higher resolution maps could be included to corroborate the results of this Study in selecting areas of highest WVC concern, as well as inform future actions.

8.2.8 Collaboration With Agency Partners and Others

Agency and other partners such as non-profit organizations can help create a culture of change within MoDOT with respect to wildlife, and provide data, guidance, and funding to help plan and create wildlife mitigation measures.

8.2.8.1 ACTION ITEMS

Develop a Memorandum of Understanding Between MoDOT and MDC

Recommendation: MoDOT and MDC can codify their working relationship with a Memorandum of Understanding on how they will work together to accommodate wildlife along Missouri roads.

The implementation of wildlife crossings aligns with the missions of both MoDOT and MDC. MoDOT's mission is to provide a world-class transportation system that is safe, innovative, reliable, and dedicated to serving customers for a prosperous Missouri. MDC's mission is to protect and manage the fish, forest, and wildlife resources of the state, and to facilitate opportunities for all citizens to use, enjoy, and learn about these resources. These shared goals were exemplified when both departments contributed non-federal match funding to support the WCPP grant that generated this Study.

Future collaborative efforts between MoDOT and MDC—such as budgeted cooperative agreements, joint grant applications, and strategic reallocation of funds—could further advance both agencies' objectives. These partnerships may help secure additional funding and support for wildlife crossing structures and connectivity projects that benefit Missouri's citizens and natural resources. A Memorandum of Understanding can help institutionalize relations at the headquarters and district levels to ensure consistent and productive working relations toward wildlife mitigation and accommodations in the future, regardless of individuals in specific positions or political changes. Several example Memorandum of Understandings can be viewed in Appendix C of *The Strategic Integration of Wildlife Mitigation into Transportation Procedures: A Manual for Agencies and Partners* (Cramer et al. 2022a).



Integrate State Wildlife Action Plan Information into Transportation STIP and LRTP

Recommendation: The Missouri State Wildlife Action Plan should be consulted in the long-range planning process and the STIP planning process.

The key to the success of Missouri's State Wildlife Action Plan is the habitat-based approach (MDC 2015d). MDC has identified and prioritized locations in Missouri that have the greatest opportunity for sustainable conservation of fish, habitat, and wildlife resources. Bringing those important locations into the TMS system with maps of habitat, as well as maps of potential habitat created in this Study, will help to inform project planning and construction.

Form a Collaborative Alliance

Recommendation: Using the Colorado, Wyoming, and Virginia models, form a collaborative alliance for wildlife, wildlife corridors, and transportation.

MoDOT can formally partner with other agencies, non-profit organizations, counties, academic institutions, Tribes, and others to create a working relationship alliance to coordinate efforts to mitigate upcoming road projects for wildlife and develop standalone wildlife projects for project nomination, educate and conduct outreach, pursue partnership funding opportunities, create policy, initiate research, and coordinate data exchange and planning (Colorado Wildlife and Transportation Alliance 2025; DiRienzo 2020; Virginia Safe Wildlife Corridors Collaborative 2025).

8.2.9 Immediate Next Steps for Implementation

There are short-term actions that can begin upon the completion of this Study.

8.2.9.1 ACTION ITEMS

Engage MoDOT Planning and Environmental Units

Recommendation: Environmental and planning staff present this WVC Study's findings and propose integration points in the transportation process.

Propose Policy Updates

Recommendation: Draft language for the EPG and LRTP that institutionalizes wildlife considerations. Start presenting draft language up the chain of command within MoDOT and present to MDC.

Pilot a Screening Tool

Recommendation: Develop a GIS-based WVC screening layer for use in project scoping with the GIS layers developed in this Study plus others that include data from MDC, USFWS, and The Nature Conservancy.

Host the First of Continuing Interagency Workshops

Recommendation: Collaborate with MDC, FHWA, and non-government organizations to create the wildlife and transportation alliance and begin to align design standards and funding strategies.

Create Metrics to Track Success of Wildlife Mitigation Measures

Recommendation: In a BMP Manual and Monitoring Protocol Manual, define performance measures for success.

See **Section 6.12.1.2** for how to best define performance measures such as crash reduction, white-tailed deer success rates, and species functional connectivity.

8.3 Funding

Funding opportunities to help finance wildlife mitigation and accommodations along transportation corridors and to help protect wildlife connectivity have been steadily increasing each year, with transportation-based grant opportunities, wildlife-related grants, and AOP funding to replace culverts that block aquatic connectivity all increasing in number and amounts allocated with reauthorization of funding mechanisms. Discussed below are the more broadly based opportunities for funding these efforts, which are by no means a comprehensive compilation.

8.3.1 Federal Transportation Funding Resources

Funding opportunities are consistently in flux due to changes in the federal administration, so it is important to check on the availability of these discretionary grant programs (Callahan et al. 2024).

8.3.1.1 THE 2021 FEDERAL INFRASTRUCTURE INVESTMENT AND JOBS ACT

The most recent Transportation Act (at the time of this writing) authorized multiple funding sources from a variety of programs to fund studies, plans, designs, and construction of wildlife crossing structures and other mitigation to reduce WVCs and restore and protect wildlife connectivity. The best known of these is the WCPP, which brought in a tsunami of funding for wildlife crossings and accommodations across the U.S. The legislation also authorized Federal, Tribal, State, and local entities to use new and existing programs to pay for wildlife mitigation measures. Callahan et al. (2024) provides greater detail on the available programs for wildlife mitigation effort funding. It is also advised to stay abreast of political progress as the next Transportation Act of 2026 is debated and signed into law.

Wildlife Crossings Pilot Program (WCPP)/Wildlife Road Crossing Program

The Wildlife Crossings Pilot Program (WCPP) brought in a tsunami of funding for wildlife crossings and accommodations across the U.S. with the passage of the 2021 Infrastructure Investment and Jobs Act. The WCPP allocated \$350 million over five years in a competitive grants program to apply to planning, designing, and constructing wildlife mitigation to reduce WVCs and to provide terrestrial and aquatic connectivity. The program is competitive, with Notices of Funding Opportunities through the program released annually. The WCPP funded much of this study.

The WCPP will end with the passage of a new Transportation Act in 2026. The WCPP may become the Wildlife Road Crossings Program in the 2026 Transportation Act. In November of 2025, a bill was introduced into the 119th U.S. Congress to amend the past 2021 Act to make the program more permanent and add additional funds of \$200 million annually from 2026 through 2031¹. Further information can be found on the USDOT FHWA WCPP website (FHWA 2025h).

Bridge Investment Program (BIP)

The Bridge Investment Program (BIP) is a competitive, discretionary program that focuses on existing bridges to reduce the overall number of bridges in poor condition, or in fair condition at risk of falling into poor condition. It also expands applicant eligibility to create opportunities for all

¹ H.R. Wildlife Road Crossings Program Reauthorization Act of 2025, H.R. 6078. 119th Cong., 1st sess. (2025).



levels of government to be direct recipients of program funds (FHWA 2025a). Aquatic connectivity and wildlife crossing structures are approved improvements for this funding source.

Nationally Significant Multimodal Freight and Highway Projects (INFRA) Grants

The Nationally Significant Multimodal Freight and Highway Projects (INFRA) grant program awards competitive grants for multimodal freight and highway projects of national or regional significance to improve the safety, efficiency, and reliability of the movement of freight and people in and across rural and urban areas (USDOT 2025b). This program would be best suited to projects that integrate wildlife crossing structures into national or regionally significant highway or freight projects (Callahan et al. 2024). Missouri won a \$92.8 million grant in this program to reconstruct three segments of the 191 miles of IS-70 that stretch across the state. The project also includes wildlife crossing infrastructure and pollinator habitat conservation.

Nationally Significant Federal Lands and Tribal Projects (NSFLTP) Program

The Nationally Significant Federal Lands and Tribal Projects (NSFLTP) program funds nationally significant projects within, adjacent to, or accessing Federal Tribal lands (FHWA 2025f).

Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program

The PROTECT program provides funding to ensure surface transportation resilience to natural hazards including climate change, sea level rise, flooding, extreme weather events, and other natural disasters through support of planning activities, resilience improvements, community resilience and evacuation routes, and at-risk coastal infrastructure (USDOT 2025c). Callahan et al. (2024) suggest this program is ideal for applicants who seek to co-benefit terrestrial and aquatic connectivity within a larger project to improve resiliency (largely for climate change) of important transportation infrastructure. Oregon secured one of these grants for \$6.1 million to replace a culvert with a bridge that would better handle the effects of flooding and rising sea levels. It will also benefit terrestrial and aquatic connectivity for wildlife and fish.

Better Utilizing Investments to Leverage Development (BUILD) Grant Program (Formerly Known as RAISE)

This program provides grants for surface transportation infrastructure projects with significant local or regional impact. The eligibility requirements of Better Utilizing Investments to Leverage Development (BUILD) allow project sponsors, including state and local governments, counties, Tribal governments, transit agencies, and port authorities, to pursue multi-modal and multi-jurisdictional projects that are more difficult to fund through other grant programs (USDOT 2025a). Wyoming DOT won an earlier BUILD award in 2019 for \$14.5 million to build several wildlife crossing structures and associated fences and other improvements near Big Piney.

Rural Surface Transportation Grant Program

The Rural Surface Transportation Grant Program supports projects that improve and expand the surface transportation infrastructure in rural areas to increase connectivity, improve the safety and reliability of the movement of people and freight, and generate regional economic growth and improve quality of life (USDOT 2025d). The eligible categories do include construction of wildlife crossing structures, projects, and strategies to reduce WVCs, and other related activities such as monitoring.

Tribal Transportation Program Safety Fund (TTPSF)

This program's funds are to address transportation safety issues identified by federally recognized Tribes through a competitive, discretionary program. Projects are chosen whose outcomes will reduce fatal and serious injuries in transportation related incidents, such as motor vehicle crashes (FHWA 2025g). Tribes can apply for funds under this program to plan for projects that improve road hazards such as WVCs.

8.3.1.2 HIGHWAY SAFETY IMPROVEMENT PROGRAM (HSIP) FUNDS

The purpose of these funds is to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-state-owned roads and roads on tribal land. HSIP requires a data-driven, strategic approach to improving highway safety on all public roads with a focus on performance (FHWA 2025d). This program has been used throughout the U.S. to fund wildlife crossing structures in areas where the crash data indicate a wildlife-vehicle collision problem area that has higher crash rates than averages in other areas of the state. It is largely a response to and funding for reducing WVCs. It does not apply to providing connectivity for wildlife. Many wildlife crossings in western states have been built with these funds; it is the larger mammals, such as deer, elk, and moose that drive the data that result in eligibility for this program's funds (**Figure 8-13**).

Figure 8-13: Utah's IS-15 Wildcat wildlife underpass built in 2004 with funding from HSIP.



Source: B. Bonebrake.

8.3.1.3 FEDERAL LANDS ACCESS PROGRAM (FLAP)

The objectives of this program are to improve transportation facilities that provide access to, are adjacent to, or are located within Federal lands. The Access Program supplements state and local resources for public roads, transit systems, and other transportation facilities, with an emphasis on high-use recreation sites and economic generators (FHWA 2025c). If the road under scrutiny provides access to federal lands such as National Parks, US Forest Service lands, BLM lands, USFWS lands, or state or Tribal lands, the wildlife crossing structures and other mitigation embedded in that road can qualify for this program. Idaho's first wildlife overpass, for example, was partially funded with these funds (**Figure 8-14**).

Figure 8-14: Idaho's SH 21 overpass (the first overpass built in Idaho) was funded in part with FLAP funds.



Source: P. Cramer.

8.3.1.4 TRANSPORTATION ALTERNATIVES PROGRAM

This program's eligible projects encompass a variety of smaller-scale transportation projects such as pedestrian and bicycle facilities, recreational trails, safe routes to school projects, community improvements such as historic preservation and vegetation management, and environmental mitigation related to stormwater and habitat connectivity (FHWA 2025b). This was the first program used by state DOTs to fund wildlife crossings in the early 2000's outside of the HSIP.

8.3.1.5 OTHER TRANSPORTATION FUNDING RESOURCES

There are several other less prominent federal transportation funding programs. Callahan et al. (2024) provides a guide to these less-common funding sources.

8.3.2 Funding from Wildlife Related Sources

8.3.2.1 STATE WILDLIFE GRANTS PROGRAM

The State Wildlife Grant Program is unique in that it gives states and territories the decision-making authority to allocate Program resources based on each jurisdiction's highest priorities for species and habitat protection (USFWS 2025b). Only the state fish and wildlife agency and the four regional associations of fish and wildlife agencies (AFWAs) (Northeast AFWA, Southeastern AFWA, Midwest AFWA, and Western AFWA) are eligible to apply. Priority for use of these funds must be placed on species of greatest conservation need and/or their habitats.

8.3.2.2 NATIONAL FISH AND WILDLIFE ASSOCIATION (NFWF)

The National Fish and Wildlife Foundation (NFWF) partners with agencies and granting organizations to provide funding for conservation solutions across the country. Two of their standard programs are listed below as potential funding sources to assist Missouri in protecting and enhancing lands important to mitigate Missouri roads for WVCs and providing wildlife connectivity.



Conservation Partners Program

This program awards competitive grants to provide technical assistance to landowners and operators of farms, ranches, and forests who participate in the federal Farm Bill conservation programs. The funds help these participants develop management plans, design and implement best practices, and participate in Farm Bill programs (National Fish and Wildlife Foundation [NFWF] 2025b). In Washington State, during outreach webinars to these types of landowners to demonstrate the results of the Washington Habitat Connectivity Plan, many landowners voiced concern that they did not know how to apply for various funding resources to place their lands in conservation easements and how to benefit from programs that could reward them for management practices that foster wildlife connectivity. This type of grant could help bring more landowners into an overall plan within Missouri to protect wildlife connectivity at the Top 10 segments this Study has identified as important to mitigate roads for WVCs and wildlife connectivity.

Lower Mississippi Alluvial Valley Restoration Fund

This fund invests in on-the-ground projects that restore, enhance, and conserve bottomland hardwood forests and wetland habitat to benefit wildlife and improve water quality within the Mississippi Alluvial Valley region of Missouri. Partners in this program include the US Forest Service, USFWS, and USDA. It is possible some funding from this program could help to protect and restore the riparian forests near the Mississippi River in Missouri that are near hot spots of WVCs and needed wildlife connectivity. (NFWF 2025d). This fund is discussed in greater detail in the AOP section below.

8.3.2.3 PITMAN ROBERTSON WILDLIFE RESTORATION ACT AND THE WILDLIFE RESTORATION PROGRAM

This Act was passed in 1937 and provides funding for states to support wildlife and their habitat restoration and conservation. The funding is from excise taxes on firearms, ammunition, and archery equipment. State wildlife agencies compete for grants from the program. States have secured this funding to build wildlife crossing structures and sponsor research (**Figure 8-15**). The state wildlife agency applies to the USFWS for these funds (USFWS 2025c).

Figure 8-15: Utah has used Pittman-Robertson Act funding to help build wildlife crossing structures such as this one under US 89 at the Arizona border, and to sponsor research on the efficacy of these structures.



Source: P. Cramer, UDOT, and Utah Division of Wildlife Resources.

8.3.2.4 GREAT AMERICAN OUTDOORS ACT

The 2020 Great American Outdoors Act was a historic investment in the protection and sustainment of the US public lands. It established the National Parks and Public Land Legacy Restoration Fund and authorized permanent funding for the LWCF, aimed at safeguarding natural areas and cultural heritage. Funding addresses access to national parks, public lands such as national wildlife refuges, roads in and to these areas, and Bureau of Indian Education funded schools. As of March 2025, Maintenance Action Teams have completed work at three USFWS locations and three National Park locations in Missouri (US Department of Interior [USDOI] 2025). Future projects could be paired with wildlife connectivity needs and WVCs locations.

8.3.2.5 AMERICA THE BEAUTIFUL CHALLENGE INITIATIVE

The America the Beautiful Challenge is a public-private grant program for locally-led ecosystem restoration projects that invest in watershed restoration, resilience, equitable access, workforce development, corridors, and connectivity, and collaborative conservation consistent with the America the Beautiful Initiative (National Wildlife Federation [NWF] 2025). This and other funding sources can be applied for through the America's Ecosystem Restoration Initiative (NFWF 2025a). The Initiative builds on the investments of the Great American Outdoors Act and its Public Legacy Restoration Fund, which was set to expire in 2025. A current bill (in late 2025) would extend the Legacy Restoration Fund through 2033 and increase authorization to \$2 billion per year. The US Forest Service has accessed these funds to help maintain trails. The Act and the continuation of the Legacy Restoration Fund could be tapped to help build wildlife crossing structures in conjunction with federal lands and trails. However, the Initiative may be rescinded by the Trump administration. President Trump also established a Make America Beautiful Again Commission to prioritize conserving national parks and outdoor recreation uses. This is an advisory commission, but it may result in potential funding opportunities.

8.3.2.6 ASSOCIATION OF FISH AND WILDLIFE AGENCIES

The AFWA coordinates among member wildlife agencies to collaborate on national issues. They have an AFWA Transportation Community of Practice group that meets every two months on the second Wednesday. This group meets to participate in webinars about wildlife and transportation, discuss member issues, and report on funding opportunities (Association of Fish and Wildlife Agencies [AFWA] n.d.).

The Multistate Conservation Grant Program

The AFWA administers this program cooperatively with USFWS. A state, public institution of higher education, or nongovernmental organization can apply for these grants. Projects proposed for this program funding must meet species and activity eligibility standards under the Wildlife Restoration Act and/or the Sport Fish Restoration Act. The proposed project must benefit multiple states: either a majority (over 50 percent) of states in a USFWS Region, a majority in an AFWA Regional Association, or at least 26; and the project must address regional or national priority needs of state fish and wildlife agencies and their partners. To be eligible, the proposal must address one or more of the Strategic Priorities. The Strategic Priorities, related to wildlife connectivity and transportation mitigation, include landscape conservation and habitat connectivity; fish and wildlife health; emerging technologies for fish and wildlife management; conservation education; and monitoring and evaluation. With these priorities, a research project in Missouri to learn about efficacy of wildlife mitigation that could benefit other states should be something that could be proposed. See AFWA's Multistate Conservation Grant Program (AFWA 2025).

8.3.2.7 MISSOURI DEPARTMENT OF CONSERVATION (MDC)

Another possible source of funding is partnering with Missouri state agencies, such as MDC, to improve terrestrial and aquatic passage across MoDOT operated roads. This would help both agencies work towards their respective missions. Some grant funding opportunities to be considered are Community Conservation Cost-Share; Community Forest Program; and Urban Waters Restoration Program. The Missouri Design for Conservation Sales Tax that supports fish, forest and wildlife conservation efforts may also be another resource to tap for wildlife mitigation projects. MDC provided funds to help support this Study.

8.3.2.8 STATE LEGISLATION AND WILDLIFE COMMISSION ALLOCATIONS

State policymakers in east, Midwest, and western states have created Acts and allocations to fund wildlife crossing structures, connectivity studies, and other activities to restore and protect wildlife connectivity and reduce WVCs. In Wyoming, the Wyoming Game and Fish Commission approved \$500,000 appropriations for wildlife crossing structures in several annual budgets for various Wyoming DOT wildlife mitigation projects. Since 2020, at least 19 states have enacted legislation that address mitigating the impacts of roads on wildlife or wildlife connectivity (Sito and Christianson 2024). In New Mexico, legislators allocated \$50 million to build wildlife crossings structures. In Utah, the policy makers allocated \$20 million toward building wildlife crossing structures, to name a few.

8.3.2.9 HUNTING/SPORTSMEN ORGANIZATIONS

Sportsmen/women hunting organizations have helped fund portions of wildlife and transportation mitigation. The Rocky Mountain Elk Foundation, Mule Deer Foundation, Sportsmen for Fish and

Wildlife, and Muley Fanatic Foundation, while mostly based in the west, have contributed funds to directly pay for wildlife crossing structures and fences, helped provide funding for wildlife research on wildlife and mitigation, helped monitor fences annually to find maintenance needs, and raised public awareness of the need to mitigate roads for wildlife. Similar organizations at the state level in Missouri would be potential collaborative partners in future wildlife mitigation projects.

8.3.2.10 UNIQUE FUNDING SOURCES

States, counties, and cities have created unique funding sources to help build wildlife crossing structures and other mitigation. Below are several examples but are by no means the only examples.

Taxes for Wildlife Crossing Structures and Wildlife Connectivity

Residents in several western counties have voted to tax themselves for wildlife connectivity. The first known county was Pima County, Arizona, home to Tucson. The initial effort raised \$45 million for wildlife crossing structures and land protection. Several wildlife underpasses and an overpass have already been built with the funds (**Figure 8-16**) (Cramer et al. 2022a).

Figure 8-16: An underpass (left) and overpass (right) under and over SH 77 in Pima County, Arizona that were constructed with funds derived from a wildlife connectivity tax.



Source: P. Cramer

Citizens Initiatives

Citizens for Safe Highway 9 in Kremmling Colorado raised funds in collaboration with Blue Valley Ranch, and Grand County Colorado for the SH 9 Wildlife Crossing structures and fences (**Figure 8-17**). DOTs in the past could not directly receive funds from citizens, but a non-profit can deliver a large check to a DOT to help support wildlife crossing structures. This has happened in other places as well, such as Park City Utah's Save People Save Wildlife non-profit's efforts that resulted in checks for tens of thousands of dollars to the Utah DOT to help build a wildlife overpass on IS-80 and erect wildlife exclusion fences.

Figure 8-17: Mule deer moving over one of the SH 9 overpasses in Colorado.



Source: J. Richert.

License Plates for Wildlife Crossings

Several states, including Wyoming and Montana (**Figure 8-18**) have created legislation to manufacture license plates with wildlife crossing artwork, with the proceeds to be transferred to a fund for wildlife crossing structures. In Wyoming's first year of the plates becoming available (2018), citizens purchased the \$180 plates (of which \$150 went toward the wildlife crossing fund) and raised over \$300,000 for wildlife mitigation (Bales 2021). These efforts go hand-in-hand with the creation of accounts, such as Montana's Big Game and Wildlife Highway Crossings and Accommodations Account, which then allow the DOTs to take donations for the effort (Drew 2025).

Figure 8-18: The winning design for Montana DOT's wildlife crossings license plate.



Source: Montana Department of Transportation

Allocating Money from Specialty Taxes

Montanans voted to legalize recreational marijuana, which is then taxed within the state. Montana House Bill 932 in 2025 allocated funds from recreational cannabis sales to have expanded uses

for conservation. The \$10 million habitat-conservation-dedicated annual funding derived from cannabis taxes will deposit five percent of those funds (approximately \$500,000) into Montana's Big Game and Wildlife Highway Crossings and Accommodations Account (Eggert 2025, Hansen 2025).

8.3.3 Funding for Aquatic Organism Passage

AOP is the removal of barriers to movement between bodies of water (Joint Committee on Fisheries Engineering and Science 2025). AOP is a national term that refers to culverts and bridges that allow natural water flow beneath roads that mimics velocity and timing of the natural stream, river, lake, or estuary water flow. Removing and replacing barriers for aquatic organisms to move beneath a road provides multiple benefits including resiliency for transportation infrastructure to withstand increased water flows due to climate change; reducing transportation agency maintenance costs for clearing debris from outdated structures that slows the movement of water and thus leads to sediment buildup; improving conditions that allow for the recovery and maintenance of fish populations, including threatened and endangered species, and other aquatic species such as crayfish; and passage opportunity for other wildlife species including some terrestrial wildlife.

If a culvert or bridge is improved for aquatic passage and is large enough for human passage, it can also serve to protect anglers and recreationists from having to cross roads while following a water course. Funding for AOP improvements to existing transportation-related culverts and bridges can be used to provide both aquatic and terrestrial connectivity. DOTs have enlarged some replacement aquatic culverts to allow for terrestrial wildlife movement, with Washington DOT becoming a leader in this approach (**Figure 8-19**). Below, several funding sources to assist with developing aquatic crossing structures are presented.

Figure 8-19: Washington DOT slightly enlarged the dimensions of this fish passage structure to allow for terrestrial wildlife movement. Monitoring by P. Cramer found black tailed deer moved beneath the highway through this structure, as planned.



Source: P. Cramer



8.3.3.1 BRIDGE INVESTMENT PROGRAM (BIP)

This program is for the planning, rehabilitation, and replacement of bridges. See the description above in the Transportation Funding Resources section.

8.3.3.2 STATE WILDLIFE GRANTS PROGRAM

These competitive grants are applied for and received by the state wildlife agency. See full description above under the Funding from Wildlife Resources.

8.3.3.3 NATIONAL FISH HABITAT PARTNERSHIP PROGRAM

The National Fish Habitat Action Plan (under the National Fish Habitat Partnership), codified through The America's Conservation Enhancement Reauthorization Act of 2024 (PL 118-198), is an attempt to address the loss and degradation of their fish habitat (National Fish Habitat Partnership 2024).

8.3.3.4 THE U.S. FOREST SERVICE LEGACY ROADS AND TRAILS REMEDIATION PROGRAM

The Legacy Roads and Trails Remediation Program supports the U.S. Forest Service mission by restoring, protecting, and maintaining crucial watersheds within our national forests and grasslands (U.S. Forest Service n.d.). Protecting threatened, endangered, and sensitive species, and community water sources, are among the top priorities for projects that improve and maintain forest access. AOP is a major area of consideration and funding for these resources. In Missouri, proposals for funding for this program would be for culverts and bridges in the Mark Twain National Forest. More information can be found at the above U.S. Forest reference, and the American Trails website (American Trails n.d.).

8.3.3.5 NATIONAL FISH AND WILDLIFE FOUNDATION FIVE STAR AND URBAN WATERS RESTORATION GRANT PROGRAM

The Five Star Program seeks to develop nationwide community stewardship of local natural resources, preserving these resources for future generations and enhancing habitat for local wildlife (NFWF 2025c). Grants seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. Funds are provided for on-the-ground restoration in areas with minority communities. Priority will be given to projects in urban, suburban and/or rural areas that advance water quality goals in environmental justice communities such as neighborhoods with high concentrations of minority and low-income populations. Grants are \$20,000 to \$50,000.

8.3.3.6 USDA NRCS REGIONAL CONSERVATION PARTNERSHIP PROGRAM (RCPP)

The RCPP is a partner-driven approach to conservation that funds solutions to natural resource challenges on agricultural land (USDA NRCS 2025c). By leveraging collective resources and collaborating on common goals, RCPP demonstrates the power of public-private partnerships in delivering results for agriculture and conservation. This program could be tapped to help protect land and aquatic resources for wildlife.



8.3.3.7 USDA NRCS EMERGENCY WATERSHED PROTECTION PROGRAM (EWP)

The EWP Program, a federal emergency recovery program, helps local communities recover after a natural disaster (USDA NRCS 2025b). Proposals need a local sponsor. Funding includes dam removal.

8.3.3.8 NOAA FISHERIES COMMUNITY-BASED HABITAT RESTORATION

The National Oceanic and Atmospheric Administration's (NOAA) Community-Based Restoration Program provides funding and technical assistance to develop habitat restoration projects that ensure fish have access to high quality habitat (National Oceanic and Atmospheric Administration [NOAA] Fisheries 2025a). Funds are for species managed by NOAA Fisheries, or those listed under the ESA.

8.3.3.9 NOAA RESTORING FISH PASSAGE THROUGH BARRIER REMOVAL GRANTS

Up to \$75 million in funding is available for fish passage projects under the Bipartisan Infrastructure Law. This funding will support projects that reopen migratory pathways and restore access to healthy habitat for fish around the country (NOAA Fisheries 2025b).

Funding will be used for fish passage that rebuilds productive and sustainable fisheries, contributes to the recovery and conservation of threatened and endangered species, enhances watershed health, promotes resilient ecosystems and communities, especially in underserved communities, and improves economic vitality, including local employment.

8.3.3.10 NATIONAL FISH AND WILDLIFE FOUNDATION LOWER MISSISSIPPI ALLUVIAL VALLEY RESTORATION FUND

As previously mentioned, the Lower Mississippi Alluvial Valley Restoration Fund invests in on-the-ground projects to restore, enhance and conserve bottomland hardwood forest and wetland habitats to benefit wildlife and improve water quality within the Mississippi Alluvial Valley region of Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri and Tennessee (NFWF 2025d). The goal of the fund is to enact projects to remove or retrofit water conveyance structures, such as dikes and levees, to improve flows between rivers and side channels to increase habitat connectivity for fish and other aquatic species. Projects that benefit gar (fish) and increase the frequency and duration of floodplain and/or oxbow connection to the Mississippi River main stem for gar are of interest. To be competitive, each aquatic connectivity proposal and/or aquatic habitat improvement proposal should include a section detailing the pre- and post-intervention freshwater fish monitoring at the site to be conducted either by the applicant or a named partner/subcontractor.

8.3.3.11 BUILD GRANT PROGRAM (FORMERLY KNOWN AS RAISE)

Funds are available for culvert replacement and planning projects. See the BUILD description in the Transportation Funding Resources Section for more details.

8.4 Prioritized Projects

This section provides a summary of the implementation, funding, and environmental considerations for each of the Top 10 areas, as previously discussed in **Section 6** and **Appendix H**.

8.4.1 Pershing State Park

Located in the Northwest MoDOT District, along U.S. 36 (MPs 83-95), the Pershing State Park Top 10 segment is an exemplary location to reduce WVCs and provide connectivity for wildlife in the area. With the land protection status of the state park on both sides of U.S.36, a private land conservation easement, natural riparian forests that are connected north and south to other areas in the landscape, and existing bridges and culverts, it is a location where wildlife mitigation can be added through small lengths of wildlife exclusion fence attached to existing bridges that wildlife are already using.

8.4.1.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with submitting grant applications for any funding sources to construct the retrofit projects (fencing, gates, and escape ramps). Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- BIP
- PROTECT
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term. The most important retrofit opportunity would be to extend fences east and west from the Locust Creek Bridges, with the west fences extending to the Higgins Ditch, and east fence to the Overflow bridge. No long-term infrastructure solutions were recommended; however, it was recommended that the retrofit of the Parson's Creek bridges occur during repairs to the bridge decking. The total costs associated with the retrofits were \$1,740,500. There were no ROW acquisitions or utility relocations assumed; however, since the entrance to the state park is within the recommended fencing, MDC would need to be closely involved in planning. Benefits from the mitigation total \$13,457,696 over 50 years, yielding a benefit cost ratio of 7.73 and payback period of 6.47 years.



Detailed mitigation and implementation recommendations for the Pershing State Park Top 10 segment can be found in **Section 6.2**.

8.4.1.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within Pershing State Park with high potential for impact include land use, noise, visual environment, federal and state listed species, Section 4(f) and 6(f), floodplains, water quality, and wetlands and streams. The remaining resources listed in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Land Use:

- Consultation with NRCS on prime farmland impacts may be required. If required, consultation would include completing Form AD-1006, the Farmland Conversion Impact Rating form.

Noise:

- Impacts to noise-sensitive receptors could necessitate abatement measures.

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.
- Consultation with MoDNR should be initiated to confirm 6(f) funding was used for the park. Subsequent coordination with the NPS will be required for any properties within the proposed mitigation methods that received Section 6(f) funding.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the Missouri State Emergency Management Agency (SEMA) may be required.
- Floodplain development permits may also be required by the Linn County Floodplain Administrator.

Water Quality:

- Coordination with MoDNR is recommended for any proposed mitigation methods that will impact Locust Creek to determine permitting needs related to Section 303(d) impaired waters.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.



Detailed environmental considerations for the Pershing State Park Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.2 Four Rivers Conservation Area

Located in the Southwest MoDOT District, along IS-49 (MPs 112-114). There are two Conservation Areas along IS-49 in this Top 10 segment: Douglas Branch and Horton Bottoms.

8.4.2.1 IMPLEMENTATION

The Horton Bottoms Conservation Area should take priority for both short-term and mid-term actions. Vegetation clearing and stump removal at existing structures should be prioritized in the short-term, along with submitting grant applications for any funding sources to construct the retrofit projects (fencing, gates, and escape ramps). Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- INFRA
- PROTECT
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP (for the IS-49 southbound bridges built in 1969)
- National Fish Habitat Partnership
- USDA NRCS RCPP

Once funding is allocated, retrofit projects should be constructed in the mid-term. The most important retrofit priority is to place wildlife fencing to the north and south of the existing bridges in the Horton Bottoms Conservation Area portion of the Top 10 segment. No long-term infrastructure solutions were recommended; however, it was recommended that the retrofit of the Marmaton River bridges occur during bridge repairs/replacement. The total costs associated with the retrofits were \$1,632,420. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$4,046,340 over 50 years, yielding a benefit cost ratio of 2.48 and payback period of 20.17 years.

Detailed mitigation and implementation recommendations for the Four Rivers Conservation Area Top 10 segment can be found in **Section 6.3**.

8.4.2.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Four Rivers Conservation Area Top 10 segment with high potential for impact include land use, visual environment, federal and state listed species, Section 4(f) and 6(f), floodplains, wetlands and streams, and socioeconomic factors. The remaining resources listed in **Appendix H** were deemed to have a moderate to low potential for impact and thus are



considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Land Use:

- Consultation with NRCS on prime farmland impacts may be required. If required, consultation would include completing Form AD-1006, the Farmland Conversion Impact Rating form.

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Vernon County Floodplain Administrator.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Socioeconomic Factors:

- Efforts to consider impacts on minority and low-income populations within the Top 10 segment should be made.

Detailed environmental considerations for the Four Rivers Conservation Area Top 10 segment can be found in **Section 4** and **Appendix H**.

8.4.3 Wappapello Reservoir

Located in the Southeast MoDOT District, along MO-34 (MP 35-38) in a lowland area of riparian forests that border the St. Francis River.

8.4.3.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with path placement through existing riprap under the St. Francis River bridge, and the placement of warning signs along westbound lanes east of the bridge. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, cattle guards, and escape ramps) should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- BIP
- PROTECT
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- Federal Lands Access Program (For Mark Twain National Forest)

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term. The top priority retrofit action is to place wildlife exclusion fencing off each corner of the St. Francis River Bridge. No long-term infrastructure solutions were recommended. The total costs associated with the retrofits were \$313,770. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$188,538 over 50 years, yielding a benefit cost ratio of 0.6 and payback period of 83.21 years.

Detailed mitigation and implementation recommendations for the Wappapello Reservoir Top 10 segment can be found in **Section 6.4**.

8.4.3.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Wappapello Reservoir Top 10 segment with high potential for impact include visual environment, architectural and archeology, terrestrial habitat, federal and state listed



species, Section 4(f) and 6(f), floodplains, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Terrestrial Habitat:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally designated critical habitat may be required.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Wayne County Floodplain Administrator.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Wappapello Reservoir Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.4 Whiteman Airforce Base and Knob Noster State Park

Located in the Kansas City MoDOT District, along RT-DD (MP 4.1-8.6) within the Knob Noster State Park, and along MO-23 (MP 15.6-17.6) parallel to the Whiteman Airforce Base.

8.4.4.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with path placement through existing riprap under the RT-DD McAdoo Creek bridge, and the placement of warning signs at the east fence end at the RT-DD Clear Fork River bridge. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, cattle guards, and escape ramps) and a long-term infrastructure solution should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- PROTECT
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- HSIP

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

It is also suggested to investigate funding opportunities in association with Department of Defense funds.

Once funding is allocated, retrofit projects should be constructed in the mid-term. The top retrofit recommendation is to place fencing east and west from the McAdoo Creek Bridge. One long-term infrastructure solution, a multi-use underpass or smaller wildlife underpass, was recommended for the SE 691st Road location within the Top 10 segment. The total costs associated with the retrofits and infrastructure solution were \$3,319,460. There were no ROW acquisitions or utility relocations assumed; however, the entrance to the state park is within the recommended fences, and MDC would have to be closely involved in planning. Benefits from the mitigation total \$11,096,496 over 50 years, yielding a benefit cost ratio of 3.29 and payback period of 15.18 years.



Detailed mitigation and implementation recommendations for the Whiteman Airforce Base and Knob Noster State Park Top 10 segment can be found in **Section 6.5**.

8.4.4.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Whiteman Airforce Base and Knob Noster State Park Top 10 segment with high potential for impact include hazardous materials, noise, visual environment, architectural and archeology, federal and state listed species, Section 4(f) and 6(f), floodplains, water quality, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Hazardous Materials:

- Phase I Environmental Site Assessments would be recommended to verify the presence/absence of hazardous waste sites related to Whiteman Airforce Base if the proposed mitigation methods would disturb any of these sites and/or if MoDOT were to acquire land in the vicinity of these sites.

Noise:

- Impacts to noise-sensitive receptors could necessitate abatement measures.

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.
- Consultation with MoDNR should be initiated to confirm 6(f) funding was used for the park. Subsequent coordination with the NPS will be required for any properties within the proposed mitigation methods that received Section 6(f) funding.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Johnson County Floodplain Administrator.



Water Quality:

- Coordination with MoDNR is recommended for any proposed mitigation methods that will impact Clear Creek to determine permitting needs related to Section 303(d) impaired waters.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Whiteman Airforce Base and Knob Noster State Park Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.5 Parma Woods Shooting Range

Located in the Kansas City MoDOT District, along IS-435 (MP 51.5-55.5) and along MO-45 (MP 6-10).

8.4.5.1 IMPLEMENTATION

Garbage clean-up at existing structures should be prioritized in the short-term, along with the maintenance of soil pathways beneath the IS-435 bridges and the placement of warning signs on MO-45 at north MP 6.49. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, and escape ramps) and long-term infrastructure solutions should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- BIP
- INFRA
- PROTECT (for box culvert replacement)
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program to help with including trails in future culverts

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- National Fish and Wildlife Foundation Five Star and Urban Waters Restoration Grant Program
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term, with fencing placements along the IS-435 bridges over River Road being the highest priority. Long-term infrastructure solutions, the replacement of existing box culverts, were recommended for several locations within the Top 10 segment. The total costs associated with the retrofits were \$521,710. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$6,712,384 over 50 years, yielding a benefit cost ratio of 12.87 and payback period of 3.89 years. These values do not include the cost or benefits of the box culvert replacements.

Detailed mitigation and implementation recommendations for the Parma Woods Shooting Range Top 10 segment can be found in **Section 6.6**.



8.4.5.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Parma Woods Shooting Range Top 10 segment with high potential for impact include noise, visual environment, architectural and archeology, federal and state listed species, Section 4(f) and 6(f), floodplains, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Noise:

- Impacts to noise-sensitive receptors could necessitate abatement measures.

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Platte County Floodplain Administrator.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Parma Wood Shooting Range Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.6 Fox River and Buck Run

Located in the Northeast MODOT District, along MO-27 (MP 0-1) and along U.S. 61 (MP 374-377). The Fox River portion of the Top 10 segment was the highest scoring hot spot in the Study.

8.4.6.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with the placement of warning signs on U.S. 61 at the Schlotter Lake culvert. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, cattle guards, and escape ramps) and long-term infrastructure solutions should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- INFRA
- PROTECT
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- HSIP

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration
- National Fish and Wildlife Foundation Lower Mississippi Alluvial Valley Restoration Fund

Once funding is allocated, retrofit projects should be constructed in the mid-term, with the installation of fencing, gates, and escape ramps at the Fox River bridges being the most important actions and the highest priority. One long-term infrastructure solution, the installation of a skylight hole in the ceiling of the 115th Street median triple box culvert, was recommended. The total costs associated with the retrofits and infrastructure solutions were \$428,980. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$359,120 over 50 years, yielding a benefit cost ratio of 0.84 and payback period of 59.7 years. These values do not include the cost or benefits of the box culvert replacements.

Detailed mitigation and implementation recommendations for the Fox River and Buck Run Top 10 segment can be found in **Section 6.7**.

8.4.6.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Fox River and Buck Run Top 10 segment with high potential for impact include land use, architectural and archeology, federal and state listed species, floodplains, water quality, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Land Use:

- Consultation with NRCS on prime farmland impacts may be required. If required, consultation would include completing Form AD-1006, the Farmland Conversion Impact Rating form.

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Lewis County Floodplain Administrator.

Water Quality:

- Coordination with MoDNR is recommended for any proposed mitigation methods that will impact the Fox River to determine permitting needs related to Section 303(d) impaired waters.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Fox River and Buck Run Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.7 Long Branch State Park

Located in the Northeast MoDOT District, along U.S. 36 (MP 122-124.4), this Top 10 segment includes the Middle Fork of the Little Chariton River.

8.4.7.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with the placement of a path over existing riprap under the Middle Fork Little Chariton River bridges and the installation of a guardrail along the north side of the westbound bridge. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, and escape ramps) should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- PROTECT
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources:

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term, with the installation of fencing, gates, and escape ramps at the Little Cariton River bridges being the highest priority. The total costs associated with the retrofits were \$681,990. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$1,723,776 over 50 years, yielding a benefit cost ratio of 2.53 and payback period of 19.8 years.

Detailed mitigation and implementation recommendations for the Long Branch State Park Top 10 segment can be found in **Section 6.8**.

8.4.7.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Long Branch State Park Top 10 segment with high potential for impact include federal and state listed species, floodplains, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:



Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Macon County Floodplain Administrator.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Long Branch State Park Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.8 Maramec Spring State Park

Located in the Central MoDOT District, along MO-8 (MP 6-8), this Top 10 segment lies fully within the Maramec Spring State Park and includes the Meramec River.

8.4.8.1 IMPLEMENTATION

Vegetation clearing at existing structures should be prioritized in the short-term, along with clearing a path in the rock/concrete under the Meramec River bridge. Vegetation clearing along the ROW at the curve near County Road 3600 is also recommended to improve driver viewshed. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, cattle guards, and escape ramps) should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- BIP
- PROTECT
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- Federal Lands Access Program (For Mark Twain National Forest)

Wildlife Related Sources

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term, with fencing on the west side of the Meramec River bridge being the highest priority. Additional fencing installation along the majority of MO-8 within the Top 10 segment was also recommended as optional supplemental mitigation. No long-term infrastructure solutions were recommended. The total costs associated with the retrofits were \$405,490 (or \$827,350 if additional fencing recommendations are implemented). There were no ROW acquisitions or utility relocations assumed; however, the entrance to the state park is within these recommended fences, and MDC would need to be closely involved in planning. Benefits from the mitigation total \$987,580 over 50 years (or \$1,678,886 if additional fencing recommendations are implemented), yielding a benefit cost ratio of 2.44 and payback period of 20.5 years (or 1.19 and 24.6 years if additional fencing recommendations are implemented).

Detailed mitigation and implementation recommendations for the Maramec Spring State Park Top 10 segment can be found in **Section 6.9**.

8.4.8.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within Maramec Spring State Park Top 10 segment with high potential for impact include architectural and archaeology, terrestrial habitat, federal and state listed species, section 4(f) and (6f), floodplains, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Terrestrial Habitat:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally designated critical habitat may be required.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Crawford and Phelps County Floodplain Administrators.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Maramec Spring State Park Top 10 segment can be found in **Section 4** and **Appendix H**.



8.4.9 Roubidoux Creek Conservation Area

Located in the Central MoDOT District, along MO-17 (MP 139-141.5), this Top 10 segment encompasses the Gasconade River. This area is different from the other Top 10 segments in this Study due to the highway's sinuous nature, steep hills on one side of the road, and a river and creek on the other.

8.4.9.1 IMPLEMENTATION

Speed limit reductions and placement of both seasonal and permanent warning signs should be prioritized in the short-term. The timing of crashes during the year should also be investigated; if crashes are seasonal, mobile message boards should be posted for both directions of traffic, warning of potential wildlife on the road. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, cattle guards, and escape ramps) should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- BIP
- PROTECT
- BUILD
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- Federal Lands Access Program (For Mark Twain National Forest)

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term, with fencing from the east side abutment of the Gasconade River Bridge eastward along MO-17 being the highest priority. No long-term infrastructure solutions were recommended. The total costs associated with the retrofits and infrastructure solutions were \$405,490. There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$3,126,341 over 50 years, yielding a benefit cost ratio of 7.71 and payback period of 6.49 years.

Detailed mitigation and implementation recommendations for the Roubidoux Creek Conservation Area Top 10 segment can be found in **Section 6.10**.



8.4.9.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Roubidoux Creek Conservation Area Top 10 segment with high potential for impact include visual environment, architectural and archaeology, terrestrial habitat, federal and state listed species, section 4(f) and (6f), floodplains, water quality, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Visual Environment:

- A visual impact assessment may be required for proposed mitigation methods.

Architectural and Archaeology:

- Consultation under Section 106 and the NHPA with the SHPO may be required. Early coordination with SHPO offices is recommended.

Terrestrial Habitat:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally designated critical habitat may be required.

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.
- Consultation with MoDNR should be initiated to confirm 6(f) funding was used for the conservation area. Subsequent coordination with the NPS will be required for any properties within the proposed mitigation methods that received Section 6(f) funding.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Pulaski County Floodplain Administrator.

Water Quality:

- Coordination with MoDNR is recommended for any proposed mitigation methods that will impact the Gasconade River to determine permitting needs related to Section 303(d) impaired waters.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.



Detailed environmental considerations for the Roubidoux Creek Conservation Area Top 10 segment can be found in **Section 4** and **Appendix H**.

8.4.10 Honey Creek Conservation Area

Located in the Northwest MODOT District, along IS-29 (MPs 70-72 and 73-74), this Top 10 segment is predominantly riparian forest along the east side of the Missouri River and is largely privately owned. The Honey Creek Conservation Area is at the southwest end.

8.4.10.1 IMPLEMENTATION

Placing erosion control netting on slopes beneath the Nodaway River bridge should be prioritized in the short-term. Grant applications for any funding sources to construct the retrofit projects (fencing, gates, and escape ramps) and long-term infrastructure solutions should also be submitted in the short-term. Applicable funding sources include the following:

Transportation Oriented Programs:

- WCPP for 2025-2026/Wildlife Road Crossing Program in the 2026 Transportation Act
- INFRA
- PROTECT
- Rural Surface Transportation Grant Program
- Transportation Alternatives Program
- HSIP

Wildlife Related Sources:

- State Wildlife Grants Program
- Conservation Partners Program – for private landowners adjacent to the area
- Pittman Robertson Program
- MDC Grants
- State Legislation and Wildlife Commission Allocation
- America the Beautiful Challenge

Aquatic Organism Funding Sources

- BIP
- National Fish Habitat Partnership
- USDA NRCS RCPP
- NOAA Fisheries Community-Based Habitat Restoration

Once funding is allocated, retrofit projects should be constructed in the mid-term, with fencing north and south of the Nodaway River bridge being the highest priority. Recommended long-term infrastructure solutions included the installation of a wildlife underpass underneath IS-29 and the installation of a larger box culvert at the Meade Creek culvert location. The total costs associated with the retrofits were \$676,010 (a total of \$1,790,530 when including the long-term infrastructure solutions). There were no ROW acquisitions or utility relocations assumed. Benefits from the mitigation total \$1,661,960 over 50 years (or \$2,659,136 when including the long-term infrastructure solutions), yielding a benefit cost ratio of 2.46 and payback period of 20.3 years (or 1.44 and 34.6 years when including long-term infrastructure solutions).

Detailed mitigation and implementation recommendations for the Honey Creek Conservation Area Top 10 segment can be found in **Section 6.11**.



8.4.10.2 ANTICIPATED ENVIRONMENTAL CONSIDERATIONS

Resources within the Honey Creek Conservation Area Top 10 segment with high potential for impact include federal and state listed species, floodplains, and wetlands and streams. The remaining resources listed for the Top 10 segment in **Appendix H** were deemed to have a moderate to low potential for impact and thus are considered less of a concern for mitigation method implementation. Possible permits and/or required coordination for resources with a high potential for impact include:

Federal and State Listed Species:

- ESA Section 7/Section 10 consultation with USFWS regarding potential impacts to federally listed species may be required.
- Consultation with MDC regarding potential impacts to state listed species may be required.

Section 4(f) and 6(f):

- Consultation with FHWA should be initiated to establish an impact designation for 4(f) resources.
- Consultation with MoDNR should be initiated to confirm 6(f) funding was used for the conservation area. Subsequent coordination with the NPS will be required for any properties within the proposed mitigation methods that received Section 6(f) funding.

Floodplains:

- A floodplain development permit or a No-Rise Certification from the SEMA may be required.
- Floodplain development permits may also be required by the Holt and Andrew County Floodplain Administrators.

Wetlands and Streams:

- Impacts to jurisdictional waters and wetlands will trigger CWA 404/401 permitting. A site visit would be required to determine the true extent of on-site jurisdictional streams or wetlands.

Detailed environmental considerations for the Honey Creek Conservation Area Top 10 segment can be found in **Section 4** and **Appendix H**.

9 References

- Abilio, Fernanda Maria, Carl Smith III, Collin Tidwell, Paul Hamel, Margaret Devall, and Ted Leininger. 2008. "Pondberry (*Lindera melissifolia*) seed predators." In: IV Congreso Forestal Latinoamericano. Merida, Venezuela. 2-8 abril 2008. 1-8.
<https://research.fs.usda.gov/treesearch/31532>.
- Acharya, Shikha, Mark Morgan., Shuangya Xu, and Mark H. Palmer. 2023. "A descriptive analysis of Deer-vehicle collisions along Missouri interstate highways". *Trees, Forests and People* 13:100409. <https://doi.org/10.1016/j.tfp.2023.100409>.
- Adams, Lowel W. and Aelred D. Geis. 1983. "Effects of Roads on Small Mammals." *Journal of Applied Ecology* 20 (2): 403-415. <https://doi.org/10.2307/2403516>.
- Ament, Robert, Sandra Jacobson, Renee Callahan, Marta Brocki, eds. 2021. *Highway crossing structures for wildlife: opportunities for improving driver and animal safety*. PSW-GTR-271. May 2021. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.
https://www.fs.usda.gov/psw/publications/documents/psw_gtr271/psw_gtr271.pdf.
- Andis, A.Z., Marcel P. Huijser, & Len Broberg. 2017. "Performance of Arch-Style Road Crossing Structures from Relative Movement Rates of Large Mammals." *Frontiers in Ecology & Evolution* 5:122. doi: 10.3389/fevo.2017.00122.
- AFWA (Association of Fish and Wildlife Agencies). N.d. "AFWA Is." Accessed December 19, 2025. <https://www.fishwildlife.org/landing>.
- AFWA. 2025. "Program Overview and Application Process." Multistate Conservation Grant Program. Accessed December 19, 2025. <https://www.fishwildlife.org/afwa-informs/multi-state-conservation-grants-program>.
- American Trails. N.d. "Legacy Trails Program." Accessed December 19, 2025.
https://www.americantrails.org/legacy-trails-program?blm_aid=122843137.
- Bales, Jaden. 2021. "Wyomingites Raise \$300k For Wildlife With License Plates." *Wyoming Wildlife Federation*. February 4, 2021. <https://wyomingwildlife.org/wyoming-raise-300k-for-wildlife-through-license-plates/>.
- Ballestero, Tom, Dave Burdick, Lauren White, Sandra Houghton, & Josh Megysey. 2023. *Design Guidance for Wetland-Road Crossings to Reduce Blanding's Turtle Mortality Risk*. November 10, 2023. Prepared by University of New Hampshire, New Hampshire Fish & Game, and New Hampshire Department of Environmental Services.
<https://www.wildlife.nh.gov/sites/g/files/ehbemt746/files/inline-documents/sonh/10nov2023-guidance-for-wetland-road-crossings-for-blandings-turtles.pdf>.

- Barthelmess, Erika L. and Margot S. Brooks. 2010. "The influence of body-size and diet on road-kill trends in mammals." *Biodiversity and Conservation* 19: 1611-1629. <https://doi.org/10.1007/s10531-010-9791-3>.
- Baxter-Gilbert, James H., Julia L. Riley, David Lesbarreres, and Jacqueline D. Litzgus, 2015. "Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness." *PLoS ONE* 10 (3): e0120537. doi:10.1371/journal.pone.0120537.
- Bellis, Mark A. 2008. "Evaluating the Effectiveness of Wildlife Crossing Structures in Southern Vermont." Master's Thesis. University of Massachusetts Amherst. <https://scholarworks.umass.edu/server/api/core/bitstreams/5f793f86-cd04-4e94-bf5e-3599e820920e/content>.
- Bhardwaj, M., K. Soanes, T.M. Straka, J.J. Lahoz-Monfort, L.F. Lumsden, and R. van de Ree. 2017. "Differential use of highway underpasses by bats." *Biological Conservation* 212 (A): 22-28. <https://doi.org/10.1016/j.biocon.2017.05.022>.
- Bhardwaj, M., K. Soanes, J.J. Lahoz-Monfort, L.F. Lumsden, and R. van de Ree. 2019. "Artificial lighting reduces the effectiveness of wildlife-crossing structures for insectivorous bats." *Journal of Environmental Management* 262:110313. <https://doi.org/10.1016/j.jenvman.2020.110313>.
- Blank, Matt, Bob Bramblett, Steven Kalinowski, Joel Cahoon, & Kyle Nixon. 2011. *Impacts of Barriers on Topeka Shiner Populations*. SD2006-07-F. March 2011. Prepared for South Dakota Department of Transportation. https://westerntransportationinstitute.org/wp-content/uploads/2016/08/4W1486_Final_Report.pdf.
- Brehme, Cheryl S., Jeff A. Tracey, Leroy R. McClenaghan, and Robert N. Fisher. 2013. "Permeability of Roads to Movement of Scrubland Lizards and Small Mammals." *Conservation Biology* 27 (4):710-720. <https://doi.org/10.1111/cobi.12081>.
- Briggler, Jeff. 2024. Overview of Select Amphibian and Reptile Species in Missouri Crossing Roads for the MoDOT Wildlife Vehicle Collision Study. November 14, 2024.
- Bouchard, Julie, Adam T. Ford, Felix E. Eigenbrod, and Lenore Fahrig. 2009. "Behavioral Responses of Northern Leopard Frogs (*Rana pipiens*) to Roads and Traffic: Implications for Population Persistence." *Ecology and Society* 14 (2):23. <http://www.ecologyandsociety.org/vol14/iss2/art23/>.
- Bouska, Wesley and Craig P. Paukert. 2010. Road Crossing Designs and Their Impact on Fish Assemblages of Great Plains Streams." *Transactions of the American Fisheries Society* 139 (1):214-222. <http://dx.doi.org/10.1577/T09-040.1>.
- Callahan, R., Keil, A., Brocki, M. 2024. *Wildlife Infrastructure Funding Guide: Funding Opportunities within the Infrastructure Investment & Jobs Act*. Prepared for ARC Solutions, NPCA, Wildlands Network. Bozeman, MT. <https://arc-solutions.org/wp-content/uploads/2024/06/Wildlife-Infrastructure-Funding-Guide.pdf>.



- Cayuela, Hugo, Eric Bonnaire, Guillelme Astruc, & Aurelien Besnard. 2019. "Transport infrastructure severely impacts amphibian dispersal regardless of life stages." *Scientific Reports* 9:8214. <https://doi.org/10.1038/s41598-019-44706-1>.
- Center for Environmental Excellence. 2025. "Context Sensitive Solutions Overview." American Association of State Highway and Transportation Officials (AASHTO). Accessed December 18, 2025. <https://environment.transportation.org/focus-areas/context-sensitive-solutions/context-sensitive-solutions-overview/>.
- Chapman, S.S., J.M. Omernik, G.E. Griffith, W.A Schroeder, T.A. Nigh, and T.F. Wilton. 2002. Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,800,000). https://dmap-prod-oms-edc.s3.us-east-1.amazonaws.com/ORD/Ecoregions/mo/moia_eco_lq.pdf.
- City of Wilsonville. 2024. "Kinsman Road Extension Project." Natural Resources. Wilsonville, Oregon. Accessed January 21, 2025. <https://www.ci.wilsonville.or.us/natural/page/kinsman-road-extension-project/>.
- Cleland, E.E. 2011. "Biodiversity and Ecosystem Stability." *Nature Education Knowledge* 3 (10):14. <https://www.nature.com/scitable/knowledge/library/biodiversity-and-ecosystem-stability-17059965/>.
- Clevenger, Anthony P. and Nigel Waltho. 2005. "Performance indices to identify attributes of highway crossing structures facilitating movement of large animals." *Biological Conservation* 121 (3):453-464. <https://doi.org/10.1016/j.biocon.2004.04.025>.
- Clevenger, Anthony P. and Marcel P. Huijser. 2011. *Wildlife Crossing Structure Handbook Design and Evaluation in North America*. FHWA-CFL/TD-11-003. March 2011. Prepared for Federal Land Highway Division. https://www.fhwa.dot.gov/clas/ctip/wildlife_crossing_structures/default.aspx#toc.
- Clevenger, Anthony P. and M. Barrueto (Eds.). 2014. *Trans-Canada Highway Wildlife and Monitoring Research, Final Report*. Prepared for Parks Canada, Radium Hot Springs, British Columbia, Canada. https://arc-solutions.org/wp-content/uploads/2015/12/Banff-TCH-Wildlife-Monitoring-Research-Final-Report-2014_withappendices1.pdf.
- Climate and Economic Justice Screening Tool. 2024. Archived Version 2.0. December 20, 2024. <https://public-environmental-data-partners.github.io/j40-cejst-2/en/downloads#3/33.47/-97.5>.
- Colley, Michael, Stephen C. Loughheed, Kenton Otterbein, & Jacqueline D. Litzgus. 2017. "Mitigation reduces road mortality of a threatened rattlesnake." *Wildlife Research* 44 (1):48-59. <https://doi.org/10.1071/WR16130>.
- Colorado Wildlife & Transportation Alliance. 2025. "Colorado Wildlife & Transportation Alliance." Accessed December 19, 2025. <https://www.coloradowta.com/home/>.

- Compton, Bradley W. 2007. *Status Assessment for the Blanding's Turtle (Emydoidea blandingii) in the Northeast*. July 2007. Prepared for University of Massachusetts, Amherst Department of Natural Resources Conservation.
https://www.blandingsturtle.org/uploads/3/0/4/3/30433006/embl_status_assessment_30jul07.pdf.
- Cook, Taylor C. and Daniel T. Blumstein. 2013. "The omnivore's dilemma: Diet explains variation in vulnerability to vehicle collision mortality." *Biological Conservation* 167:310-315. <https://doi.org/10.1016/j.biocon.2013.08.016>.
- Cooke, Sophia C., Andrew Balmford, Paul F. Donald, Stuart E. Newson, and Alison Johnston. 2020. "Roads as a contributor to landscape-scale variation in bird communities." *Nature Communications* 11:3125. <https://doi.org/10.1038/s41467-020-16899-x>.
- Cramer, Patricia. 2012. *Determining Wildlife Use of Wildlife Crossing Structures Under Different Scenarios*. UT-12.07. May 2012. Prepared for Utah Department of Transportation Research Division. <https://rosap.ntl.bts.gov/view/dot/24501>.
- Cramer, Patricia. 2014. *Wildlife Crossing Structures in Utah: Determining the Best Designs*. November 2014. Prepared for Utah Division of Wildlife Resources.
https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/6307b215e6e38251198a5ed8/1661448759210/UT+FINAL_REPORT_WILDLIFE_CROSSINGS_IN_UTAH_NOV_25_2014.pdf.
- Cramer, Patricia. 2016. *US 91 Monitoring mule deer and elk movements through corrugated steel wildlife crossing culvert and use of escape ramps*. Prepared for Utah Division of Wildlife Resources.
- Cramer, Patricia & Joseph Flower. 2016. *Testing new technology to restrict wildlife access to highways: phase 1*. <https://rosap.ntl.bts.gov/view/dot/32771>.
- Cramer, Patricia & Robert Hamlin. 2016. *Testing new technology to restrict wildlife access to highways: phase 2*. <https://rosap.ntl.bts.gov/view/dot/32790>.
- Cramer, Patricia & Robert Hamlin. 2017. *Evaluation of Wildlife Crossing Structures on US 93 in Montana's Bitterroot Valley*. FHWA/MT-17-003/8194. January 2017. Prepared for Montana Department of Transportation. <https://doi.org/10.21949/1518235>.
- Cramer, Patricia & Robert Hamlin. 2019a. *U.S. Highway 89 Kanab-Paunsaugunt Wildlife Crossing and Existing Structures Research*. UT-19.19. Prepared for Utah Department of Transportation. https://rosap.ntl.bts.gov/view/dot/63544/dot_63544_DS1.pdf.
- Cramer, Patricia & Robert Hamlin. 2019b. *US 189 Wildlife Crossing Structures and Escape Ramp Monitoring*. Final Report. Prepared for Utah Department of Transportation.
https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/6307deb2247ead644d4600f5/1661460157748/UT+US+189+Wildlife+Crossing+Structures+and+Escape+Ramps+Monitoring_FINAL+REPORT+3-3-2020.pdf.



- Cramer, Patricia & Robert Hamlin. 2019c. *US 191 Monticello Crossing Structure and Double Cattle Guard Monitoring Project*. Final Report. Prepared for Utah Department of Transportation. <https://www.wildlifeconnectivity.org/utah-reports>.
- Cramer, Patricia & Robert Hamlin. 2021. *US 160 Dry Creek Wildlife Research*. Final Report. Prepared for Colorado Department of Transportation. <https://c95055.eos-intl.net/C95055/OPAC/Details/Record.aspx?IndexCode=-1&TaskCode=1327989&HitCount=1&CollectionCode=2&SortDirection=Descending&CurrentPage=1&CurrentLinkCode=MC95055|2935711|1|4048439&SelectionType=0&SearchType=1&BibCode=MC95055|2935711|1|4048439>.
- Cramer, Patricia & Robert Hamlin. 2025a. *State Highway 13 Wildlife Mitigation Measures 2024 Annual Report*. Study Number 120.02. Prepared for Colorado Department of Transportation. <https://www.wildlifeconnectivity.org/colorado-sh13-reports-1>.
- Cramer, Patricia & Robert Hamlin. 2025b. *Utah SR 73 Eagle Mountain Mule Deer Crosswalk and Wildlife Detection Driver Warning System Research, 2024 Annual Report*. May 2025. Prepared for Utah Department of Transportation. <https://www.wildlifeconnectivity.org/utah-eagle-mtn>.
- Cramer, Patricia & Robert Hamlin. 2025c. *US 160/SH151 Wildlife Mitigation Research Project 2024 Annual Report*. Study Number R122.01. Prepared for Colorado Department of Transportation. <https://www.wildlifeconnectivity.org/colorado-chimney-reports>.
- Cramer, Patricia & Chris McGinty. 2018. *Prioritization of Wildlife-vehicle Conflict in Nevada*. Volume 604. Research Report. Nevada Department of Transportation.
- Cramer, P., J. Kintsch, L. Loftus-Otway, N. Dodd, K. Andrews, T. Brennan, P. Basting, J. Gagnon, L. Frazier, and L. Sielecki. 2022a. *TPF-358 Strategic Integration of Wildlife Mitigation into Transportation Procedures*. Prepared for Nevada Department of Transportation. <https://pooledfund.org/Details/Study/610>.
- Cramer, Patricia, Jean-Luc E. Cartron, Kenneth C. Calhoun, Jeffery W. Gagnon, Matthew B. Haverland, Mark L. Watson, Samuel A. Cushman, Ho Yi Wan, Julie A. Kutz, Jeremy N. Romero, Terence J. Brennan, Jeanette A. Walther, Chad D. Loberger, Haley P. Nelson, Trent D. Botkin, & James G. Hirsch. 2022b. *New Mexico Wildlife Corridors Action Plan*. June 2022. Prepared for New Mexico Department of Transportation and New Mexico Department of Fish & Game. https://wildlifeactionplan.nmdotprojects.org/wp-content/uploads/sites/39/2022/07/Wildlife-Corridors-Action-Plan_June-2022_FINAL-reduced.pdf.
- Dabbs, Janet. 2015. "Millions Of Dollars To Save A Tiny Fish? Conservation Dept. Says Niangua Darter Is Worth It." *Lake Expo.com*, November 2016. https://www.lakeexpo.com/news/lake_news/millions-of-dollars-to-save-a-tiny-fish-conservation-dept-says-niangua-darter-is-worth/article_eab8454a-b34a-11e6-a94e-53c1900f53df.html.
- DiRienzo, Sara. 2020. "Game and Fish and WYDOT's 'Wildlife Crossing' initiative to make roads safer for wildlife and drivers." Cheyenne Region News. *Wyoming Game & Fish*

Department. February 18, 2020. <https://wgfd.wyo.gov/News/Game-and-Fish-and-WYDOT%E2%80%99s-%E2%80%98Wildlife-Crossing%E2%80%99-init>.

DoD (Department of Defense). 2022. *Recommended Best Management Practices for the Blanding's Turtle (Emydoidea blandingii) on Department of Defense Installations*. March 2022. Prepared by the DoD Partners in Amphibian and Reptile Conservation for the DoD Legacy Resource Management Program. https://parcplace.org/wp-content/uploads/2022/10/BLANDINGS-TURTLE_BMP_Final_508.pdf.

Dodd, Norris, Jeffery W. Gagnon, Amanda L. Manzo, & Raymond E. Schweinsburg. 2007. "Video Surveillance to Assess Highway Underpass Use by Elk in Arizona." *Journal of Wildlife Management* 71(2): 637-645. <https://www.jstor.org/stable/4495227>.

Dodd, Norris L., Jeffrey W. Gagnon, Susan Boe, Amanda Manzo, & Raymond E. Schweinsburg. 2007. *Evaluation of Measures to Minimize Wildlife-Vehicle Collisions and Maintain Permeability Across Highways: Arizona Route 260*. FHWA-AZ-07-50. August 2007. Prepared for Arizona Department of Transportation. https://apps.azdot.gov/files/ADOTLibrary/publications/project_reports/pdf/az540.pdf.

Dodd, Norris L., Jeffrey W. Gagnon, Scott C. Sprague, Susan Boe, & Raymond E. Schweinsburg, 2010. *Assessment of Pronghorn movements and strategies to promote highway permeability: US Highway 89*. FHWA-AZ-10-619. Prepared by the Arizona Fish and Game Department. <https://rosap.nrl.bts.gov/view/dot/23088>.

Dodd, Norris L., Jeffery W. Gagnon, Scott Sprague, Susan Boe, & Raymond E. Schweinsburg. 2012. *Wildlife Accident Reduction Study and Monitoring: Arizona State Route 64*. Final Report 626. November 2012. Prepared for Arizona Department of Transportation. https://apps.azdot.gov/files/ADOTLibrary/publications/project_reports/pdf/az626.pdf.

Donaldson, Bridget M. 2005. "Use of highway underpasses by large mammals and other wildlife in Virginia and factors influencing their effectiveness." *UC Davis Road Ecology Center* 433-441. <https://escholarship.org/uc/item/0t36v00w>.

Donaldson, Bridget, Young-Jun Kweon, & Lewis Narwold Lloyd. 2016. "Roadside Activity and Behavior of White-Tailed Deer and Other Wildlife near Unfenced Underpasses." *Transportation Research Record: Journal of the Transportation Research Board* 2571:29-38. DOI: 10.3141/2571-04.

Donaldson, Bridget M. & Kaitlyn E.M. Elliott. 2020. *Enhancing Existing Isolated Underpasses With Fencing to Decrease Wildlife Crashes and Increase Habitat Connectivity*. FHWA/VTRC 20-R28. May 2020. Prepared for Virginia Department of Transportation. <https://vtrc.virginia.gov/media/vtrc/vtrc-pdf/vtrc-pdf/20-R28.pdf>.

Donaldson, B, J. Gillespie, and R. Danese. 2024. *Valuing wildlife crashes and calculating benefits and costs for safety improvement projects*. ITE Journal of Transportation Professionals Annual Meeting Proceedings. Pages 35-40.



- Drew, Micah. 2025. "Montana wildlife crossing license plate revealed." *Daily Montanan*. November 18, 2025. <https://dailymontanan.com/2025/11/18/montana-wildlife-crossing-license-plate-revealed/>.
- Eggert, Amanda. 2025. "Governor signs bill to shift marijuana tax revenues." *Montana Free Press*. May 16, 2025. <https://montanafreepress.org/2025/05/16/governor-signs-bill-to-shift-marijuana-tax-revenues/>.
- ESRI. n.d. "How Hot Spot Analysis (Getis-Ord Gi*) Works." ArcGIS Pro. Accessed February 5, 2025. <https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-hot-spot-analysis-getis-ord-gi-spatial-stati.htm>.
- Fairbank, Elizabeth Rose. 2013. "Use and Effectiveness of Wildlife Crossing Structures with Short Sections of Wildlife Fencing in Western Montana." Master's Thesis. University of Montana. <https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=5183&context=etd>.
- FEMA (Federal Emergency Management Agency). 2023. "Glossary." Accessed March 17, 2025. <https://www.fema.gov/about/glossary>.
- FEMA. 2024. "Flood Data Viewers and Geospatial Data." March 28. <https://www.fema.gov/flood-maps/national-flood-hazard-layer>.
- Ferguson, Howard L., Michael Atamian, Brian Cosentino, Brian Hall, Darren Kavangh, Brad McRae, and Andrew Shirk. 2012. *Washington Connected Landscapes Project: Analysis of the Columbia Plateau Ecoregion Appendix A.3: Habitat Connectivity for Black-Tailed Jackrabbit (Lepus californicus) in the Columbia Plateau Ecoregion*. Prepared by Washington Wildlife Habitat Connectivity Working Group. https://waconnected.org/wp-content/uploads/2013/09/A3_Black-tailed%20jackrabbit_ColumbiaPlateau_2012.pdf.
- FHWA (Federal Highway Administration). 2024. "FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2024." Office of Highway Policy Information. June 2024. https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.cfm.
- FHWA. 2025a. "Bridge Investment Program." Bridges and Structures. September 2025. <https://www.fhwa.dot.gov/bridge/bip/>.
- FHWA. 2025b. "Fact Sheets." Infrastructure Investment and Jobs Act. September 2025. <https://www.fhwa.dot.gov/infrastructure-investment-and-jobs-act/ta.cfm>.
- FHWA. 2025c. "Federal Lands Access Program (FLAP)." Federal Lands. November 2025. <https://highways.dot.gov/federal-lands/flap>.
- FHWA. 2025d. "Highway Safety Improvement Program (HSIP)." Safety. October 2025. <https://highways.dot.gov/safety/hsip>.
- FHWA. 2025e. "National Culvert Removal, Replacement, and Restoration Grants (Culvert AOP Program)." Infrastructure Investment and Jobs Act. September 2025. <https://www.fhwa.dot.gov/infrastructure-investment-and-jobs->

[act/culverts_fact_sheet.cfm#:~:text=The%20IIJA%20establishes%20the%20National.sp
end%20most%20of%20their%20lives.](#)

FHWA. 2025f. "Nationally Significant Federal Lands and Tribal Projects (NSFLTP) Program." Federal Lands – Significant. October 2025. <https://highways.dot.gov/federal-lands/significant>.

FHWA. 2025g. "Tribal Transportation Program Safety Fund (TTPSF)." Safety. November 2025. <https://highways.dot.gov/federal-lands/tribal/safety/funds>.

FHWA. 2025h. "Wildlife Crossings Pilot Program." Federal Lands. October 2025. <https://highways.dot.gov/federal-lands/wildlife-crossings/pilot-program>.

Finder, Rebecca A., John L. Roseberry, & Alan Woolf. 1999. "Site and landscape conditions at white-tailed deer/vehicle collision locations in Illinois." *Landscape and Urban Planning* 44(2-3): 77-85. [https://doi.org/10.1016/S0169-2046\(99\)00006-7](https://doi.org/10.1016/S0169-2046(99)00006-7).

Fleming, Parker and Thomas M. Neeson. 2020. "Effects of transportation infrastructure on fishes in the Ozark and Ouachita Mountains." *Transportation Research Part D: Transport and Environment* 86:102451. <https://doi.org/10.1016/j.trd.2020.102451>.

Flower, J.P. 2016. *Emerging technology to exclude wildlife from roads: electrified pavement and deer guards in Utah, USA*. Graduate Thesis. Utah State University. <https://digitalcommons.usu.edu/etd/4944/>.

Ford, Adam T. and Lenore Fahrig. 2007. "Diet and body size of North American mammal road mortalities." *Transportation Research Part D: Transport and Environment* 12 (7):498-505. <https://doi.org/10.1016/j.trd.2007.07.002>.

Gagnon, J. W., N. L. Dodd, K. S. Ogren, and R. E. Schweinsburg. 2011. "Factors associated with use of wildlife underpasses and importance of long-term monitoring." *Journal of Wildlife Management* 75:1477-1487. <https://doi.org/10.1002/jwmq.160>.

Gagnon, J. W., N. L. Dodd, S. Sprague, R. Nelson, C. Loberger, S. Boe, and R. E. Schweinsburg. 2013. *Elk movement associated with high-traffic highway: Interstate 17*. FHWA-AZ-13-647. March 2013. Prepared for Arizona Department of Transportation. https://rosap.nhtl.bts.gov/view/dot/25867/dot_25867_DS1.pdf.

Gagnon, J.W., N.L. Dodd, S.C. Sprague, C.D. Loberger, S. Boe, and R. E. Schweinsburg. 2014. *Evaluation of measures to promote desert bighorn sheep highway permeability: U.S. Highway 93*. FHWA-AZ-14-677. January 2014. Prepared for Arizona Department of Transportation. <https://rosap.nhtl.bts.gov/view/dot/26912>.

Gagnon, Jeffery W., Chad D. Loberger, Scott C. Sprague, Kari S. Ogren, Susan L. Boe, & Raymond E. Schweinsburg. 2015. "Cost-effective approach to reducing collisions with elk by fencing between existing highway structures." *Human-Wildlife Interactions* 9 (2):248-264. <https://doi.org/10.26077/z5kk-s204>.



- Gagnon, J. W., C. D. Loberger, S. C. Sprague, S. R. Boe, K. S. Ogren, and R. E. Schweinsburg. 2017a. *Wildlife-vehicle collision mitigation on State Route 260: Mogollon Rim to Show Low*. FHWA-AZ-17-706. Prepared for Arizona Department of Transportation. https://rosap.ntl.bts.gov/view/dot/37206/dot_37206_DS1.pdf.
- Gagnon, J.W., C.D. Loberger, K.S. Ogren, S.C. Sprague, S.R. Boe, and R.E. Schweinsburg. 2017b. *Evaluation of desert bighorn sheep overpass effectiveness: U.S. Route 93 long-term monitoring*. FHWA-AZ-17-710. May 2017. Prepared by Arizona Department of Transportation. https://apps.azdot.gov/files/ADOTLibrary/publications/project_reports/pdf/spr710.pdf.
- Gagnon, J.W., N.L. Dodd, S.C. Sprague, K.S. Ogren, C.D. Loberger, and R.E. Schweinsburg. 2019. "Animal-activated highway crosswalk: Long-term impact on elk-vehicle collisions, vehicle speeds, and motorist braking response." *Human Dimensions of Wildlife*: 1-16. <https://doi.org/10.1080/10871209.2019.1551586>.
- Gantchoff, Mariela G., Laura Conlee, Melanie R. Boudreau, Raymond B. Iglay, Charles Anderson, & Jerrold L. Belant. 2022. "Spatially-explicit population modeling to predict large carnivore recovery and expansion." *Ecological Modelling* 470:110033. <https://doi.org/10.1016/j.ecolmodel.2022.110033>.
- Garrah, Evelyn, Ryan K. Danby, Ewen Eberhardt, Glenn M. Cunnington, & Scott Mitchell. 2015. "Hot Spots and Hot Times: Wildlife Road Mortality in a Regional Conservation Corridor." *Environmental Management* 56 (4). <http://dx.doi.org/10.1007/s00267-015-0566-1>.
- Gehring, Thomas M and Robert K. Swihart. 2004. "Home Range and Movements of Long-Tailed Weasels in a Landscape Fragmented by Agriculture." *Journal of Mammalogy* 85 (1):79-86. [https://doi.org/10.1644/1545-1542\(2004\)085%3C0079:HRAMOL%3E2.0.CO;2](https://doi.org/10.1644/1545-1542(2004)085%3C0079:HRAMOL%3E2.0.CO;2).
- Goldfarb, Ben. 2023. "Projects That Help Wildlife Navigate Highways Gain Speed." *Audubon Magazine*, Fall 2023. <https://www.audubon.org/news/projects-help-wildlife-navigate-highways-gain-speed>.
- Graham, Bill. 2020. "Healthy Streams, Healthy State." *Missouri Conservationist*, November 1. <https://mdc.mo.gov/magazines/missouri-conservationist/2020-11/healthy-streams-healthy-state>.
- Gregory, Andrew, Emma Spence, Paul Beier, & Emily Garding. 2021. "Toward Best Management Practices for Ecological Corridors." *Land* 10 (2):140. <https://doi.org/10.3390/land10020140>.
- Gunson, Kari, David Seburn, Julia Kintsch, and Joe Crowley. 2016. *Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario*. April 2016. Prepared for Ontario Ministry of Natural Resources and Forestry. https://files.ontario.ca/bmp_herp_2016_final_final_resized.pdf.



- Hall, Sawyer, Chad L., Thomas H. 2012. *Mitigating roadway impacts to migratory mule deer - A case study with underpasses and continuous fencing.* https://migrationinitiative.org/wp-content/uploads/2022/12/Sawyer_et_al_2012_WSB.pdf.
- Hansen, Jordan. 2025. "Wildlife crossing bills get governor's signature." *Daily Montanan*. August 26, 2025. <https://dailymontanan.com/2025/08/26/wildlife-crossing-bills-get-governors-signature/>.
- Harmon, T. G. Bahar, and F. Gross. 2018. *Crash costs for highway safety analysis*. FHWA-SA-17-071. January 2018. Prepared for Federal Highway Administration. <https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-09/fhwasa17071.pdf>.
- Heaven, Paul C., Jacqueline D. Litzgus, and M. Tim Tinker. 2019. "A Unique Barrier Wall and Underpass to Reduce Road Mortality of Three Freshwater Turtle Species." *Copeia* 107 (1):92-99. <https://doi.org/10.1643/CH-18-137>.
- Hill, Jacob E., Travis L. DeVault, and Jerrold L. Belant. 2020. "Research note: A 50-year increase in vehicle mortality of North American mammals." *Landscape and Urban Planning* 197:103746. <https://doi.org/10.1016/j.landurbplan.2020.103746>.
- Hillard, Liz. 2023. "Monitoring of Road Crossing Structures in Southern Appalachia Reveals Use by Timber Rattlesnakes." *Wildlands Network*. March 23, 2023. <https://www.wildlandsnetwork.org/news/monitoring-crossing-structures-reveals-timber-rattlesnakes>.
- Holmes, Susan. 2023. "Do Wildlife Crossings Help Birds? Absolutely!" *Wildlife & Wild Places*. Environment America. Published July 21. <https://environmentamerica.org/updates/do-wildlife-crossings-help-birds-absolutely/>.
- Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament, and P.T. McGowen. 2009. "Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: A decision support tool." *Ecology and Society* 14(0): 15. <https://www.jstor.org/stable/26268301>.
- Huijser, M. P., E. R. Fairbanks, and F. D. Abra. 2017. *The reliability and effectiveness of a radar-based animal detection system*. RP 247. September 2017. Prepared for Idaho Department of Transportation. <https://rosap.nhtl.bts.gov/view/dot/34943>.
- Huijser, M. P., W. Camel-Means, E. R. Fairbank, J. P. Purdum, T. D. H. Allen, A. R. Hardy, J. Graham, J. S. Begley, P. Basting, and D. Becker. 2016. *US 93 North post-construction wildlife-vehicle collision and wildlife crossing monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana*. FHWA/MT-16-009/8208. November 2016. Montana Department of Transportation. <https://westerntransportationinstitute.org/wp-content/uploads/2019/03/US-93-North-Post-Construction-Wildlife-Vehicle-Collision-and-Wildlife-Crossing-Monitoring-MT-Phase-II-Report-Nov-2016.pdf>.
- Huijser, MP, RJ Ament, M Bell, AP Clevenger, ER Fairbank, KE Gunson, T. McGuire. "Animal Vehicle Collision Reduction and Habitat Connectivity Pooled Fund Study – Literature



- Review." 701-18-803. Prepared for Nevada Department of Transportation. December 2021. https://westerntransportationinstitute.org/wp-content/uploads/2021/12/4w7576_Huijser_et al_WVC_ConnectivityLiteratureReview_PooledFundStudyFinalReport_2021.pdf.
- Huijser, Marcel P. & Samantha C. Getty. 2023. *Effective Jump-outs for White-tailed Deer and Mule Deer*. FHWA/MT-23-004/9923-808. September 2023. Prepared for the Montana Department of Transportation. https://ftp.mdt.mt.gov/other/webdata/external/research/docs/research_proj/wildlife_fences_jumpouts/Interim-Report-1.pdf.
- Illinois DNR. 2024. "Thirteen-Lined Ground Squirrel." Wild About Illinois Wild Mammals. Accessed December 27, 2024. <https://dnr.illinois.gov/education/wildaboutpages/wildaboutwildmammals/wildaboutmammalsrodents/wawmthirteenlinedgroundsquirrel.html>.
- Indiana DNR. 2024. "Eastern Massasauga Rattlesnake." Animals. Accessed December 4, 2024. <https://www.in.gov/dnr/fish-and-wildlife/wildlife-resources/animals/eastern-massasauga-rattlesnake/>.
- iNaturalist. 2017. "GLOBAL Roadkill Observations." Accessed March 3, 2025. <https://www.inaturalist.org/projects/global-roadkill-observations>.
- Jackson, Scott, D. 2003. *Design and construction of aquatic organism passage at road-stream crossings: Ecological considerations in the design of river and stream crossings*. Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA. <https://escholarship.org/uc/item/8q73q820>.
- Jacobson, Sarah L. 2005. *Mitigation Measures for Highway-caused Impacts to Birds*. USDA Forest Service General Technical Report PSW-GTR-191. Prepared by USDA Forest Service, Redwood Sciences Laboratory, Pacific Southwest Research Station. https://www.fs.usda.gov/psw/publications/documents/psw_gtr191/psw_gtr191_1043-1050_jacobson.pdf.
- Jager, Henriette I., James A. Chandler, Kenneth B. Lepla, and Webb Van Winkle. 2001. "A Theoretical Study of River Fragmentation by Dams and its Effects on White Sturgeon Populations." *Environmental Biology of Fishes* 60:347-361. <https://doi.org/10.1023/A:1011036127663>.
- Jochimsen, Denim M., Charles R. Peterson, Kimberly M. Andrews, and J. Whitfield Gibbons. 2004. *A Literature Review of the Effects of Roads on Amphibians and Reptiles and the Measures Used to Minimize Those Effects*. Prepared for Idaho Fish and Game Department & USDA Forest Service. <https://idfg.idaho.gov/old-web/docs/wildlife/collisionAmphibRep.pdf>.
- Joint Committee on Fisheries Engineering and Science. 2025. "What is Aquatic Organism Passage/Fish Passage?" American Fisheries Society. Accessed December 19, 2025.



<https://fishpassagejointcommittee.fisheries.org/about/what-is-aquatic-organism-passage-fish-passage/>.

Jones, Elizabeth R., Dr. Richard Lancia, & Dr. Phil Doerr. 2008. *The Effectiveness of Wildlife Crossing Structures for Black Bears in Madison County, North Carolina*.

FHWA/NC/2006-62. August 15. Prepared for North Carolina Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/21345>.

Kilgore, Roger T., Bart S. Bergendahl, & Rollin H. Hotchkiss. 2010. *Culvert Design for Aquatic Organism Passage*. FHWA-HIF-11-008. October 2010. Prepared for Central Federal Lands Highway Division.

<https://www.fhwa.dot.gov/engineering/hydraulics/pubs/11008/hif11008.pdf>.

Kintsch, Julia & Dr. Patricia C. Cramer. 2011. *Permeability of Existing Structures for Terrestrial Wildlife: A Passage Assessment System*. WA-RD 777.1. July 2011. Prepared for Washington State Department of Transportation.

<https://www.wsdot.wa.gov/research/reports/fullreports/777.1.pdf>.

Kintsch, Julia, Sandra Jacobson, & Patricia Cramer. 2015. "The Wildlife Crossing Guilds Decision Framework: A Behavior-based Approach to Designing Effective Wildlife Crossing Structures." *Proceedings of the 2015 International Conference on Ecology and Transportation (ICOET 2015) Session*. Vol. 201. 2015.

Kintsch, J., P. Basting, M. McClure, and J.O. Clarke. 2019. *Western Slope wildlife prioritization study*. CDOT-2019-01. April 2019. Prepared by Colorado Department of Transportation.

<https://doi.org/10.13140/RG.2.2.24949.19684>.

Kintsch, J., P. Cramer, P. Singer, and M. Cowardin. 2021. State Highway 9 wildlife crossings monitoring final report. Study Number 115.01. Prepared for Colorado Department of Transportation.

<https://c95055.eos-intl.net/C95055/OPAC/Details/Record.aspx?BibCode=2940331>.

Knutson, Melinda G., Jennifer H. Herner-Thogmartin, Wayne E. Thogmartin, Joshua M. Kapfer, and John C. Nelson. 2018. "Habitat Selection, Movement Pattern, and Hazards Encountered by Northern Leopard Frogs (*Lithobates pipiens*) in an Agricultural Landscape." *Herpetological Conservation and Biology* 13 (1):113-130.

https://www.herpconbio.org/Volume_13/Issue_1/Knutson_etal_2018.pdf.

Kozarek, Jessica, Jay Hatch, & Britney Mosey. 2017. *Culvert Length and Interior Lighting Impacts to Topeka Shiner Passage*. MN/RC 2017-44. November 2017. Prepared for Minnesota Department of Transportation. <https://mdl.mndot.gov/flysystem/fedora/2023-01/201744.pdf>.

LWCF (Land and Water Conservation Fund). 2025. "Past Projects."

<https://lwcf.tplgis.org/mappast/>.

- LeClere, Jeffrey B. 2018. *Anaxyrus cognatus: Great Plains Toad*. 2018. Prepared for MN DNR. <https://www.dnr.state.mn.us/rsq/profile.html?action=elementDetail&selectedElement=AAABB01050>.
- Leete, Peter. 2014. *Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001*. Version 4, October 2014. Prepared for Minnesota Department of Natural Resources. https://files.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_full_document.pdf.
- Lesinski, Grzegorz. 2007. "Bat road casualties and factors determining their number." *Mammalia* 71 (3):138-142. <http://dx.doi.org/10.1515/MAMM.2007.020>.
- Martinez-Medina, Daniela, Sate Ahmad, Maria Fernanda Gonzalez-Rojas, and Heinrich Reck. 2021. "Wildlife crossings increase bat connectivity: Evidence from Northern Germany." *Ecological Engineering* 174:106466. <https://doi.org/10.1016/j.ecoleng.2021.106466>.
- Martins, Andreza M., Fernanda M. Abilio, Plinio Goncalves de Oliveira, Raquel Partelli Feltrin, Fernanda Scheffer Alves de Lima, Priscilla de O. Antonelli, Daniela Teixeira Vilela, Carl G. Smith III, Collin Tidwell, Paul Hamel, Margaret Devall, Kristina Connor, Theodor Leininger, Nathan Schiff, & A. Dan Wilson. 2015. "Pondberry (*Lindera melissifolia*, Lauraceae) seed and seedling dispersers and predators." *Global Ecology and Conservation* 4:358-368. <https://doi.org/10.1016/j.gecco.2015.07.008>.
- Massachusetts Division of Fisheries & Wildlife. 2015. *Blanding's Turtle (Emydoidea blandingii)*. Updated 2015. Prepared by the Massachusetts Division of Fisheries & Wildlife Natural Heritage & Endangered Species Program. <https://response.epa.gov/site/download.ashx?counter=416972>.
- McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). 2012. "Reptile Biodiversity: Standard Methods for Inventory and Monitoring." Berkeley: University of California Press. <https://www.jstor.org/stable/10.1525/j.ctt1pp0x5>.
- Missouri Conservation Heritage Foundation. 2025. "Improving Low Water Crossings Helps Nangua Darter and Other River Animals." Missouri Conservation Heritage Foundation. Accessed January 17, 2025. <https://mochf.org/improving-low-water-crossings-helps-nangua-darter-and-other-river-animals/>.
- MDC (Missouri Department of Conservation). 2008a. "Nangua Darter (*Etheostoma nanguae*): Guidelines for Landowners Using Conservation Practices." Updated September 9, 2008. <https://efotg.sc.egov.usda.gov/references/public/MO/Nanguadarter.pdf>.
- MDC. 2008b. "Topeka Shiner (*Notropis topeka*): Guidelines for Landowners Using Conservation Practices." Updated September 9, 2008. <https://efotg.sc.egov.usda.gov/references/public/MO/Topekashiner.pdf>.



- MDC. 2014. *Missouri White-Tailed Deer Management Plan*. October 27, 2014.
https://mdc.mo.gov/sites/default/files/mdcd7/downloads/deer_management_plan.pdf.
- MDC. 2015a. "Best Management Practices for Construction and Development Projects: Niangua Darter (*Etheostoma nianguae*).” Updated September 2015.
<https://mdc.mo.gov/sites/default/files/2020-06/NianguaDarterBMP.pdf>.
- MDC. 2015b. "Best Management Practices for Construction and Development Projects: Prairie Massasauga (*Sistrurus tergeminus*) and Eastern Massasauga (*Sistrurus catenatus*).” Updated September 2015. <https://mdc.mo.gov/sites/default/files/2020-06/PrairieEasternMassasaugaBMP.pdf>.
- MDC. 2015c. "Best Management Practices for Construction and Development Projects: Topeka Shiner (*Notropis topeka*). Updated September 2015.
<https://mdc.mo.gov/sites/default/files/2020-06/TopekaShinerBMP.pdf>.
- MDC. 2015d. *Missouri State Wildlife Action Plan*. https://mdc.mo.gov/sites/default/files/2020-04/SWAP_0.pdf.
- MDC. 2018. *Elk in Missouri*. May 2018. <https://mdc.mo.gov/sites/default/files/2020-07/ElkInMissouri.pdf>.
- MDC. 2020a. *Missouri Black Bear Management Plan 2020-2030*. April 2020.
<https://mdc.mo.gov/sites/default/files/2020-07/Bear%20Management%20Plan%202020-2030%20FINAL.pdf>.
- MDC. 2020b. *Missouri Elk Management Plan*. March 11, 2020.
https://mdc.mo.gov/sites/default/files/mdcd7/downloads/Elk_Management_Plan_FINAL.pdf.
- MDC. 2020c. *The Missouri Comprehensive Conservation Strategy*. 2020.
<https://mdc.mo.gov/sites/default/files/2024-03/CCS.pdf>.
- MDC. 2022a. "Best Management Practices for Construction and Development Projects: Black-Tailed Jackrabbit (*Lepus californicus*).” Updated August 2022.
<https://mdc.mo.gov/sites/default/files/2022-08/BlacktailedJackrabbit%20BMP.pdf>.
- MDC. 2022b. "Best Management Practices for Construction and Development Projects: Topeka Shiner (*Notropis topeka*).” Updated September 2022.
https://mdc.mo.gov/sites/default/files/2022-10/202209_TopekaShiner.pdf.
- MDC. 2022c. *Missouri Deer Season Summary & Population Status Report*. 2022. Prepared by MDC Deer and Wildlife Health Program Staff: Science Branch.
<https://mdc.mo.gov/sites/default/files/2023-09/2022DeerPopulationStatusReport.pdf>.
- MDC. 2023. *Missouri Black Bear Program*. 2023. https://mdc.mo.gov/sites/default/files/2024-09/Annual_Bear_Report_2023.pdf.



- MDC. 2024a. "Field Guide." Discover Nature. Accessed December 2, 2024. <https://mdc.mo.gov/discover-nature/field-guide>.
- MDC. 2024b. "Caves and Karst." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/caves-karst>.
- MDC. 2024c. "Cliffs." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/cliffs-and-talus/cliffs>.
- MDC. 2024d. "Forests and Woodlands." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/forests-woodlands>.
- MDC. 2024e. "Glades." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/glades>.
- MDC. 2024f. "Grasslands, Prairies, and Savannas." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/grasslands-prairies-savannas>.
- MDC. 2024g. "Lakes, Ponds, and Reservoirs." Accessed January 8, 2025. Habitats. <https://mdc.mo.gov/discover-nature/habitats/built-environments/lakes-ponds-reservoirs>.
- MDC. 2024h. "Prairies." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/grasslands-prairies-savannas/prairies>.
- MDC. 2024i. "Rivers and Streams." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/rivers-streams>.
- MDC. 2024j. "Roadsides, Industrial Sites, Mining Areas." Habitats. Accessed January 8, 2025. <https://mdc.mo.gov/discover-nature/habitats/built-environments/roadsides-industrial-sites-mining-areas>.
- MDC. 2024k. "Savannas." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/grasslands-prairies-savannas/savannas>.
- MDC. 2024l. "Stream Edges." Habitats. Accessed January 8, 2025. <https://mdc.mo.gov/discover-nature/habitats/stream-edges#:~:text=Riparian%20areas%20include%20stream%20edge,bottomland%20forests%2C%20and%20riverfront%20forests>.
- MDC. 2024m. "Talus." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/cliffs-and-talus/talus>.
- MDC. 2024n. "Wetlands." Habitats. Accessed November 21, 2024. <https://mdc.mo.gov/discover-nature/habitats/wetlands>.
- MDC. 2024o. "Wildlife Facts." Wildlife. Accessed November 21, 2024. <https://mdc.mo.gov/wildlife/wildlife-facts>.



- MDC. 2025a. "Missouri Natural Heritage Program." <https://mdc.mo.gov/your-property/responsible-construction/missouri-natural-heritage-program>.
- MDC. 2025b. *Missouri White-tailed Deer Management Plan 2025-2034*. https://mdc.mo.gov/sites/default/files/2025-02/Missouri_White-Tailed_Deer_Management_Plan_2025.pdf.
- MoDNR (Missouri Department of Natural Resources). N.d.a "Environmental Site Tracking and Research Tool (E-Start). Accessed June 19, 2025. <https://dnr.mo.gov/waste-recycling/long-term-stewardship-lts/environmental-site-tracking-research-tool-e-start>.
- MoDNR. N.d.b. "State Historic Preservation Office." Accessed May 28, 2025. <https://mostateparks.com/page/state-historic-preservation-office>.
- Minnesota DNR. 2008. "Blanding's Turtle (*Emydoidea blandingii*). Environmental Review Fact Sheet Series: Endangered, Threatened, and Special Concern Species of Minnesota. Updated March 2008. https://files.dnr.state.mn.us/natural_resources/animals/reptiles_amphibians/turtles/blandings_turtle/factsheet.pdf.
- Minnesota DNR. 2024. "Rare Species Guide: *Mustela nivalis*." Minnesota's endangered, threatened, and special concern species. Accessed December 27, 2024. <https://www.dnr.state.mn.us/rsg/profile.html?action=elementDetail&selectedElement=AMAJF02020>.
- MoDOT (Missouri Department of Transportation). 2022a. "Fast Facts." Accessed November 14, 2024. <https://www.modot.org/fast-facts>.
- MoDOT. 2022b. "Roadkill increases as nights grow cooler." Published October 5, 2022. <https://www.modot.org/node/27169>.
- MoDOT. 2022c. "Traffic Volume Maps." Accessed November 14, 2024. <https://www.modot.org/traffic-volume-maps>.
- MoDOT. 2023. *Missouri statewide wildlife vehicle collision (WVC) reduction analysis and hotspot mitigation measure feasibility study project proposal narrative*. Application for Federal Highway Administration Fiscal Years (FY) 2022-2023 Wildlife Crossings Pilot Program (WCPP). Funding Opportunity Number: 693JJ323NF00011. https://www.modot.org/sites/default/files/documents/MoDOT_Proposal_Narrative_FHWA_WCPP_Final_7.26.2023.pdf.
- MoDOT. 2024. "Watch Out for Deer Along Roadways in October and November." Published October 1, 2024. <https://www.modot.org/node/56596>.
- MoDOT. 2025a. "121.2 The Planning Framework for Transportation Decision-Making." Engineering Policy Guide. Updated June 17, 2025. https://epg.modot.org/index.php?title=121.2_The_Planning_Framework_for_Transportation_Decision-Making#121.2.5_Establish_Vision.



MoDOT. 2025b. "127.16 Wetland and Stream Mitigation." Engineering Policy Guide. Updated June 17, 2025.

https://epg.modot.org/index.php?title=127.16_Wetland_and_Stream_Mitigation.

MoDOT. 2025c. "138 Project Development Chronology." Engineering Policy Guide. Updated June 17, 2025.

https://epg.modot.org/index.php?title=Category:138_Project_Development_Chronology.

MoDOT. 2025d. "606 Guardrail and Guard Cable." Engineering Policy Guide. Updated June 17, 2025. https://epg.modot.org/index.php/Category:606_Guardrail_and_Guard_Cable.

MoDOT. 2025e. "607 Fencing." Engineering Policy Guide. Updated June 17, 2025.

https://epg.modot.org/index.php?title=Category:607_Fencing.

MoDOT. 2025f. "611 Embankment Protection." Engineering Policy Guide. Updated June 17, 2025. https://epg.modot.org/index.php?title=Category:611_Embankment_Protection.

MoDOT. 2025g. "640 Pavement and Median Drainage." Engineering Policy Guide. Updated June 17, 2025.

https://epg.modot.org/index.php?title=Category:640_Pavement_and_Median_Drainage.

MoDOT. 2025h. "700 Structures and Hydraulics." Engineering Policy Guide. Updated June 17, 2025.

https://epg.modot.org/index.php?title=Category:700_STRUCTURES_AND_HYDRAULIC_S.

MoDOT. 2025i. "Condition of State Highways -5c." Chapter 5: Managing Our Assets – 1st Quarter 2025. Accessed June 23, 2025. <https://www.modot.org/condition-state-highways-5c>.

MoDOT. 2025j. "District Office Locations." Accessed February 28, 2025.

<https://www.modot.org/district-office-locations>.

MoDOT. 2025k. "Governor's Rural Routes Program." Missouri Infrastructure Investment: Rural Routes Program. Accessed June 23, 2025. <https://www.modot.org/governors-rural-routes-program>.

MoDOT. 2025l. "Long-Range Transportation Plan and State Freight and Rail Plan Updates." Accessed December 18, 2025. <https://www.modot.org/lrtp-sfrp>.

MoDOT. 2025m. "Missouri Counties by MoDOT District." Accessed February 28, 2025.

<https://www.modot.org/district-office-locations>.

MoDOT. 2025n. "Missouri High-Priority Unfunded Needs." October 2025. Accessed December 18, 2025. <https://www.modot.org/sites/default/files/documents/High-Priority%20Unfunded%20Needs%202025Oct.pdf>.



- MoDOT. 2025o. "Other Areas of Employment at MoDOT." Accessed February 25, 2025. <https://www.modot.org/other-areas-employment-modot>.
- MoDOT. 2025p. "Safety Assessment for Every Roadway." Accessed December 18, 2025. https://epg.modot.org/forms/general_files/TS/SAFER_Document.pdf.
- MoDOT. 2025q. "Statewide Transportation Improvement Program: 2025-2029." Accessed June 21, 2025. <https://www.modot.org/statewide-transportation-improvement-program-stip>.
- Mori, Jameson, William Brown, Daniel Skinner, Peter Schlichting, Jan Novakofski, and Nohra Mateus-Pinilla. 2024. "An Updated Framework for Modeling White-Tailed Deer (*Odocoileus virginianus*) Habitat Quality in Illinois, USA." *Ecology and Evolution* 14 (11): e70487. <https://doi.org/10.1002/ece3.70487>.
- Morse, Susan. 2024. "Wildlife Corridors: Wildlife refuges provide vital passage for birds, fish and mammals on the move." Accessed March 10, 2025. <https://www.fws.gov/story/wildlife-corridors>.
- MSS (Missouri Speleological Survey). 2025. "Missouri Cave Facts." Accessed February 2, 2026. <https://www.mospeleo.org/missouri-cave-count/>.
- MU Extension. 2024. *Missouri Economy Indicators: Population Trends 2020-23*. Volume 5, Issue 9. July 2024. https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pro/ExCEED/Docs/MissouriEconomy_PopulationTrends_v5i9_15July2024.pdf.
- Myczko, Tukasz., Tim H. Sparks, Piotr Skórka, Zuzanna M. Rosin, Zbigniew Kwieciński, Marcin T. Górecki, and Piotr Tryjanowski. 2017. "Effects of local roads and car traffic on the occurrence pattern and foraging behaviour of bats." *Transportation Research Part D: Transport and Environment* 56:222-228. <https://doi.org/10.1016/j.trd.2017.08.011>.
- National Fish Habitat Partnership. 2024. "National Fish Habitat Partnership." Accessed December 19, 2025. <https://fishhabitat.org/>.
- NFWF (National Fish and Wildlife Foundation). 2025a. "America's Ecosystem Restoration Initiative." Accessed December 19, 2025. <https://www.nfwf.org/programs/americas-ecosystem-restoration-initiative>.
- NFWF. 2025b. "Conservation Partners Program." Accessed December 19, 2025. <https://www.nfwf.org/programs/conservation-partners-program>.
- NFWF. 2025c. "Five Star Program." Accessed December 19, 2025. <https://www.nfwf.org/programs/five-star-program>.
- NFWF. 2025d. "Lower Mississippi Alluvial Valley Restoration Fund." Accessed December 19, 2025. <https://www.nfwf.org/programs/lower-mississippi-alluvial-valley-restoration-fund>.



- NPS (National Park Service). 2025. "National Register of Historic Places (NRHP) GIS Public Dataset." Accessed May 28, 2025.
<https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466>.
- NOAA (National Oceanic & Atmospheric Administration) Fisheries. 2025a. "Community-Based Habitat Restoration." Habitat Conservation. Accessed December 19, 2025.
<https://www.fisheries.noaa.gov/national/habitat-conservation/community-based-habitat-restoration>.
- NOAA Fisheries. 2025b. "Restoring Fish Passage Through Barrier Removal Grants." Funding Opportunities. Updated January 10, 2025.
<https://www.fisheries.noaa.gov/grant/restoring-fish-passage-through-barrier-removal-grants>.
- National Wildlife Federation. 2025. "NFWF America the Beautiful Challenge." Programs.
<https://fundingnaturebasedsolutions.nwf.org/programs/nfwf-america-the-beautiful-challenge/>.
- Ochs, Alison E., Robert K. Swihart, and Mike R. Saunders. 2024. "A comprehensive review of the effects of roads on salamanders." *Landscape Ecology* 39 (77).
<https://doi.org/10.1007/s10980-024-01867-3>.
- Osborn, D.A., W.D. Gulsby, D.W. Stull, B.S. Cohen, R.J. Warren, K.V. Miller, & G.R. Gallagher. 2010. *Development and Evaluation of Devices Designed to Minimize Deer-Vehicle Collisions: Phase II*. FHWA-GA-10-0702. December 2010. Prepared for Georgia Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/23441>.
- Paterson, James E., Tanya Pulfer, Emma Horrigan, Smera Sukumar, Brittney I. Vezina, Ryan Zimmerling, Christina M. Davy. 2021. "Individual and synergistic effects of habitat loss and roads on reptile occupancy." *Global Ecology and Conservation* 31:e01865.
<https://doi.org/10.1016/j.gecco.2021.e01865>.
- Perkin, Joshua S., Keith B. Gido, Arthur R. Cooper, Thomas F. Turner, Megan J. Osborne, Eric R. Johnson, and Kevin B. Mayes. 2015. "Fragmentation and dewatering transform Great Plains stream fish communities." *Ecological Monographs* 85 (1):73-92.
<https://doi.org/10.1890/14-0121.1>.
- Pierce, Robert A., Jason Sumners, and Emily Flinn. 2022. *Ecology and Management of White-tailed Deer in Missouri*. November 2022. University of Missouri Extension.
<https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pub/pdf/agguides/wildlife/g09479.pdf>.
- Posey, John. 2012. "Climate Change Impacts on Transportation in the Midwest." In: *U.S. National Climate Assessment Midwest Technical Input Report*. J. Winkler, J. Andersen, H. Hatfield, D. Bidwell, and D. Brown, coordinators. https://glisa.umich.edu/wp-content/uploads/2021/02/MTIT_Transportation.pdf.

- Proulx, Catherine L., Gabrielle Fortin, & Gabriel Blouin-Demers. 2014. "Blanding's Turtles (*Emydoidea blandingii*) Avoid Crossing Unpaved and Paved Roads." *Journal of Herpetology* 48 (2):267-271. <https://doi.org/10.1670/12-176>.
- Purdum, Jeremiah P. 2013. *Acceptance of Wildlife Crossing Structures on US Highway 93 Missoula, Montana*. Graduate Student Theses, Dissertations, & Professional Papers. 47. <https://scholarworks.umt.edu/etd/47>.
- Rajewski, Jillian A., Henry R. Campa III, Gary J. Roloff, and Steven M. Gray. 2024. *Eastern Massasauga Rattlesnake (Sistrurus catenatus) Detection and Space Use Near Roads in the Southern Lower Peninsula of Michigan, USA*. July 1, 2024. Prepared for Michigan Department of Transportation. <https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Programs/Research-Administration/Final-Reports/SPR-1726-Report.pdf>.
- RSMo § 252.240. 1984. <https://revisor.mo.gov/main/OneSection.aspx?section=252.240>.
- Rudnick, Doborah, Sadie J. Ryan, Paul Beier, Samuel A. Cushman, Fred Dieffenbach, Clinton Epps, Leah R. Gerber, Joel N. Hartter, Jeff S. Jenness, Julia Kintsch, Adina M. Merenlender, Ryan M. Perkl, Damian V. Perziosi, & Stephen C. Trombulack. 2012. *The Role of Landscape Connectivity in Planning and Implementing Conservation and Restoration Priorities*. Issues in Ecology, Report No. 16. Fall 2012. Prepared for the Ecological Society of America. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1018&context=geog_facpub.
- Russell, Amy L., Calvin M. Butchkoski, Leslie Saidak, and Gary F. McCracken. 2009. "Road-killed bats, highway design, and the commuting ecology of bats." *Endangered Species Research* 8:49-60. <http://dx.doi.org/10.3354/esr00121>.
- Saunders, Mark. 2020. "Coyote, badger travel under California highway together in video reminiscent of Disney movie." Lifestyle. KOAA News5 Southern Colorado. Updated February 5. <https://www.koaa.com/lifestyle/coyote-badger-travel-under-california-highway-together-in-video-reminiscent-of-disney-movie>.
- Sawaya, Michael A., Anthony P. Clevenger, & Steven T. Kalinowski. 2013. "Demographic Connectivity for Ursid Populations at Wildlife Crossing Structures in Banff National Park." *Conservation Biology* 27 (4):721-730. <https://doi.org/10.1111/cobi.12075>.
- Sawyer, H., C. LeBeau, and T. Hart. 2012. "Mitigating roadway impacts to migratory mule deer, A case study with underpasses and continuous fencing." *Wildlife Society Bulletin* 36(3): 492-498. <https://doi.org/10.1002/wsb.166>.
- Seiler, Andreas U. 2003. "The toll of the automobile: Wildlife and roads in Sweden". Doctor's dissertation. <https://pub.epsilon.slu.se/388/1/Silvestria295.pdf>.

- Shepard, D.B., Kuhns, A.R., Dreslik, M.J., and Phillips, C.A. 2008a. "Roads as Barriers to Animal Movement in Fragmented Landscapes." *Animal Conservation* 11 (4):288-296. <https://doi.org/10.1111/j.1469-1795.2008.00183.x>.
- Shepard, Donald B., Michael J. Dreslik, Benjamin C. Jellen, and Christopher A. Phillips. 2008b. "Reptile Road Mortality around an Oasis in the Illinois Corn Desert with Emphasis on the Endangered Eastern Massasauga." *Copeia* 2:350-359. <https://doi.org/10.1643/CE-06-276>.
- Shew, Justin J., Brian D. Greene, & Francis E. Durbian. 2012. "Spatial Ecology and Habitat Use of the Western Foxsnake (*Pantherophis vulpinus*) on Squaw Creek National Wildlife Refuge (Missouri)." *Journal of Herpetology* 46 (4):539-548. <https://doi.org/10.1670/10-111>.
- Shilling, Fraser M. & David P. Waetjen. 2015. "Wildlife-vehicle collision hotspots at US highway extents: scale and data source effects." *Nature Conservation* 11:41-60. <https://doi.org/10.3897/natureconservation.11.4438>.
- Simpson, Nova O., Kelley M. Stewart, Cody Schroeder, Mike Cox, Kari Huebner, & Tony Wasley. 2016. "Overpasses and underpasses: Effectiveness of crossing structures for migratory ungulates." *The Journal of Wildlife Management* 80(8): 1370-1378. <https://doi.org/10.1002/jwmq.21132>.
- Singh, Navinder J., Michelle Etienne, Goran Spong, Frauke Ecke, & Birger Hornfeldt. 2024. "Linear infrastructure and associated wildlife accidents create an ecological trap for an apex predator and scavenger." *Science of The Total Environment* 955: 176934. <https://doi.org/10.1016/j.scitotenv.2024.176934>.
- Sito, Erin & Logan Christian. 2024. *State of the States: A look at how far U.S. state habitat connectivity legislation has advanced and what is working*. Prepared for the State of the States: Trends and Insights Report. 2024. <https://www.ncelenviro.org/app/uploads/2024/05/SoS-Master-Report-FINAL-5.14.pdf>.
- Slater, Steven J., Dustin M. Maloney, & Jessica M. Taylor. 2022. "Golden eagle use of winter roadkill and response to vehicles in the western United States." *The Journal of Wildlife Management* 86:6(e22246). <https://doi.org/10.1002/jwmq.22246>.
- Smith, D. J., D. Marsh, K. E. Gunson, and S. Tonjes. 2015. *Monitoring and adaptive management of road impacts and mitigation*. Pages 240-261 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. "Roads and Ecological Infrastructure: Concepts and Applications for Small Animals." Johns Hopkins University Press, Baltimore, MD.
- Sullivan, John M. 2011. "Trends and characteristics of animal-vehicle collisions in the United States." *Journal of Safety Research* 42 (1):9-16. <https://doi.org/10.1016/j.jsr.2010.11.002>.



Tennessee Wildlife Resources Agency. n.d. "Mammals in Tennessee." Accessed November 21, 2024. <https://www.tn.gov/twra/wildlife/mammals.html>.

Transportation Research Board. 2025. "Practices for Wildlife Passage and Habitat Connectivity." NCHRP 25-77 (RFP).
<https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5896>.

TRIP. 2006. *The Interstate Highway System in Missouri: Saving Lives, Time and Money. A report on the condition, impact, use and future needs of Missouri's Interstate highway system.* Prepared by TRIP. June 2006.
<https://www.modot.org/sites/default/files/documents/TRIP%5B1%5D.pdf>.

University of Wyoming. 2022. Mitigation Mapper. <https://migrationinitiative.org/content/migration-mapper>.

USCB (U.S. Census Bureau). 2025. Explore Census Data. <https://data.census.gov/>.

USCB. 2019. "Sex by Age." American Community Survey (ACS) 5-Year Estimates Detailed Tables, Table B01001. Accessed on June 25, 2025.
<https://data.census.gov/table/ACS5Y2019.B01001?q=310XX00US17860,25300,27620,27900,28140,40620,41140,41180,42740,44180&y=2019&d=ACS+5-Year+Estimates+Detailed+Tables>.

USCB. 2021. "Total Population." ACS 5-Year Estimates Detailed Tables, Table B01003. Accessed November 20, 2025.
<https://data.census.gov/table/ACS5Y2021.B01003?t=-00>.

USCB. 2023a. "Annual Business Survey: Statistics for Employer Firms by Race for the U.S.: 2023." Table AB00MYCSA01B. Accessed November 21, 2025.
<https://data.census.gov/table/ABSCS2023.AB00MYCSA01C?t=Business+and+Owner+Characteristics:Other+Owner+Characteristics:Owner+Race+and+Ethnicity:Owner+Sex>.

USCB. 2023b. "Detailed Household Language by Household Limited English Speaking Status." American Community Survey, ACS 5-Year Estimates Subject Tables, Table B16002. Accessed November 18, 2025. <https://data.census.gov/table?q=B16002>.

USCB. 2023c. "Nonemployer Statistics by Demographics series (NES-D): Statistics for Employer and Nonemployer Firms by Industry and Race for the U.S., States, Metro Areas, Counties, and Places: 2023. Table AB00MYNESD01C.
<https://data.census.gov/table/ABSNESD2023.AB00MYNESD01C?t=Business+and+Owner+Characteristics:Other+Owner+Characteristics:Owner+Race+and+Ethnicity:Owner+Sex>.

USCB. 2023d. "Poverty Status in the Past 12 Months." American Community Survey, ACS 5-Year Estimates Detailed Tables, Table S1701. Accessed on November 24, 2025.
<https://data.census.gov/table/ACS5Y2023.S1701?t=Income+and+Poverty>.



- USCB. 2023e. "Sex by Age." American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B01001. Accessed on June 25, 2025.
<https://data.census.gov/table/ACSDT5Y2023.B01001?q=310XX00US17860,25300,27620,27900,28140,40620,41140,41180,42740,44180&y=2023&d=ACS+5-Year+Estimates+Detailed+Tables&moe=false>.
- USCB. 2024. "QuickFacts: Arkansas; Oklahoma; Missouri". Accessed June 25, 2025.
<https://www.census.gov/quickfacts/fact/table/AR,OK,MO/PST045224>.
- USDA (United States Department of Agriculture) NRCS (National Resources Conservation Service). 2025a. Ecological Site Descriptions. Accessed June 19, 2025.
<https://www.nrcs.usda.gov/getting-assistance/technical-assistance/ecological-sciences/ecological-site-descriptions>.
- USDA NRCS. 2025b. Emergency Watershed Protection Program. Accessed December 19, 2025. <https://www.nrcs.usda.gov/programs-initiatives/emergency-watershed-protection>.
- USDA NRCS. 2025c. "Regional Conservation Partnership Program (RCPP)." Accessed December 19, 2025. <https://www.nrcs.usda.gov/programs-initiatives/regional-conservation-partnership-program>.
- USDA NRCS. 2025d. "Web Soil Survey." July 31, 2019.
<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.
- USDOI (United States Department of the Interior). 2025. "Missouri: Great American Outdoors Act National Parks and Public Land Legacy Restoration Fund." Accessed December 19, 2025. <https://www.doi.gov/sites/default/files/documents/2025-08/2025-gaoa-missouri-state-factsheet.pdf>.
- USDOT (United States Department of Transportation). 2024. "MPDG – Areas of Persistent Poverty and Historically Disadvantaged Communities." April 9, 2024.
- USDOT. 2025a. "Better Utilizing Investments to Leverage Development (BUILD) Grant Program." November 2025. <https://www.transportation.gov/BUILDgrants>.
- USDOT. 2025b. "The INFRA Grant Program." Grants. May 2025.
<https://www.transportation.gov/grants/infra-grant-program>.
- USDOT. 2025c. "Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation Program (PROTECT)." Routes. February 2025.
<https://www.transportation.gov/rural/grant-toolkit/promoting-resilient-operations-transformative-efficient-and-cost-saving>.
- USDOT. 2025d. "The Rural Surface Transportation Grant Program." Grants. May 2025.
<https://www.transportation.gov/grants/rural-surface-transportation-grant-program>.



- USEPA (United States Environmental Protection Agency). 2024. "Learn About Streams." Section 404 of the Clean Water Act. October 10, 2024. <https://www.epa.gov/cwa-404/learn-about-streams>.
- USEPA. 2025a. "How's My Waterway?" June 2, 2025. <https://mywaterway.epa.gov/>.
- USEPA. 2025b. "NEPAssist." February 6, 2025. <https://www.epa.gov/nepa/nepassist>.
- USFWS (U.S. Fish & Wildlife Service). 2020. "Updated Eagle Nest Survey Protocol." Published April 21, 2020. <https://www.fws.gov/media/updated-eagle-nest-survey-protocol>.
- USFWS. 2021. "Bald Eagle (*Haliaeetus leucocephalus*)." USFWS Migratory Bird Program. Published February 2021. <https://www.fws.gov/sites/default/files/documents/bald-eagle-fact-sheet.pdf>.
- USFWS. 2024a. "Eastern Massasauga." Accessed December 4, 2024. <https://www.fws.gov/species/eastern-massasauga-sistrurus-catenatus>.
- USFWS. 2024b. "National Wetlands Inventory (NWI)." October 27. <https://www.fws.gov/program/national-wetlands-inventory/download-state-wetlands-data>.
- USFWS. 2024c. "Range-Wide Indiana Bat & Northern Long-Eared Bat Survey Guidelines." Published March 2024. https://www.fws.gov/sites/default/files/documents/2024-10/2024_usfws_rangewide_ibat-nleb_survey_guidelines.pdf.
- USFWS. 2024d. "Threats to Birds: Collisions – Road Vehicles." Accessed December 26, 2024. <https://www.fws.gov/story/threats-birds-collisions-road-vehicles>.
- USFWS. 2025a. "IPaC (Information for Planning and Consultation)". Accessed June 19, 2025. <https://ipac.ecosphere.fws.gov/>.
- USFWS. 2025b. "State Wildlife Grants." Programs. Accessed December 19, 2025. <https://www.fws.gov/program/state-wildlife-grants/what-we-do#:~:text=Funding%20for%20the%20State%20Wildlife,size%20and%20total%20land%20area>.
- USFWS. 2025c. "Wildlife Restoration." Programs. Accessed December 19, 2025. <https://www.fws.gov/program/wildlife-restoration>.
- U.S. Forest Service. N.d. "Legacy Roads and Trails." Managing the Land: Forests and Grasslands. Accessed December 19, 2025. <https://www.fs.usda.gov/managing-land/national-forests-grasslands/legacy-roads-trails>.
- U.S. Forest Service Stream-Simulation Working Group. 2008. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*. Prepared for National Technology and Development Program. May 2008. https://www.fs.usda.gov/biology/nsaec/fishxing/aop_pdfs.html.



- USGS (United States Geological Survey). 2023a. "National Hydrography Dataset (NHD)." Published October 1. <https://www.usgs.gov/national-hydrography/national-hydrography-dataset>.
- USGS. 2023b. "National Land Cover Database (NLCD) 2021." Published July 24. <https://www.sciencebase.gov/catalog/item/647626cbd34e4e58932d9d4e>.
- USGS GAP (Gap Analysis Project). 2021. "GAP Status Code Assignment: Assumptions, Criteria, and Methods." Updated February 2021. https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/GAP%20Status%20Code%20Assignment_2021.pdf.
- USGS GAP. 2024. Protected Areas Database of the United States [PAD-US] 4.0. April 25. Accessed December 9, 2024. <https://doi.org/10.5066/P96WBCHS>.
- Virginia Safe Wildlife Corridors Collaborative. 2025. "Virginia Safe Wildlife Corridors Collaborative." Accessed December 19, 2025. <https://vswcc.weebly.com/>.
- Waldheim, Nicole, Elizabeth Wemple, P.E, Joseph Fish. 2015. *Applying Safety Data and Analysis to Performance-Based Transportation Planning*. FHWA-SA-15-089. Prepared for U.S. Department of Transportation. November 2015. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa15089data_anl.pdf.
- Waring, G.H., J.L. Griffis, & M.E. Vaughn. 1991. "White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality." *Applied Animal Behaviour Science* 29 (1-4):215-223. [https://doi.org/10.1016/0168-1591\(91\)90249-W](https://doi.org/10.1016/0168-1591(91)90249-W).
- Western Ecological Research Center. 2018. "Toad Crossing Ahead: New Study Tests Elevated Roads." *U.S. Geological Survey News*, August 28. <https://www.usgs.gov/news/toad-crossing-ahead-new-study-tests-elevated-roads-underpasses-rare-toad>.
- Will County Forest Preserve District. 2021. "What's the difference?: Common snapping turtle vs. alligator snapping turtle." *The Buzz*. Published June 9. Available at <https://www.reconnectwithnature.org/news-events/the-buzz/what-difference-common-alligator-snapping-turtle/>.
- Wilson, A.B., J.M. Baker, E.A. Ainsworth, J. Andresen, J.A. Austin, J.S. Dukes, E. Gibbons, B.O. Hoppe, O.E. LeDee, J. Noel, H.A. Roop, S.A. Smith, D.P. Todey, R. Wolf, and J.D. Wood. 2023. "Ch. 24. Midwest." In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. <https://doi.org/10.7930/NCA5.2023.CH24>.
- Woltz, Hara W., James P. Gibbs, and Peter K. Ducey. 2008. "Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis." *Biological Conservation* 141 (11):2745-2750. <https://doi.org/10.1016/j.biocon.2008.08.010>.



Zeller, Katherine A., David W. Wattles, and Stephen Destefano. 2020. "Evaluating methods for identifying large mammal road crossing locations: black bears as a case study." *Landscape Ecology* 35:1799-1808. <https://doi.org/10.1007/s10980-020-01057-x>.

Zurcher, Arthur A., Dale W. Sparks, & Victoria J. Bennett. 2010. "Why the bat did not cross the road?" *Acta Chiropterologica* 12(2): 337-340. Doi: 10.3161/150811010X537918.



A

Literature Review

Literature Review

Previous studies on WVC reduction strategies, the effectiveness of various wildlife crossing structures, and habitat connectivity plans have been conducted throughout the United States. Relevant studies were reviewed and the findings summarized below to help inform available WVC reduction strategies for this Study.

Transportation Mitigation

Multiple methods to mitigate the negative impacts of transportation on wildlife have been implemented throughout the United States and around the world. Mitigation solutions are prescribed on an individual-by-individual basis, based on the location, fiscal constraints, wildlife species involved, land ownership, and other factors. To make a more educated prescription, it is necessary to know the various options and their known effectiveness at reducing WVCs and promoting wildlife connectivity.

The following discussion defines the different types of actions available to reduce WVCs and help wildlife move beneath or above the road. WVC reduction strategies can be broadly categorized into methods that specifically target wildlife behavior and methods that specifically target motorist behavior. Multiple transportation mitigation strategies can be used in combination where appropriate; however, careful consideration should be given to the life history traits of target species, the potential effects various crossing structures may have on those species, and the design of the mitigation strategies (Clevenger and Huijser 2011; Gagnon et al. 2018; Huijser et al. 2016; Jaeger and Fahrig 2004; Soanes et al. 2016).

Table 1 summarizes the most commonly used wildlife and transportation mitigation methods, including difficulty (effort and time) of deployment, overall effectiveness in both promoting wildlife connectivity and reducing WVCs, frequency of use throughout the United States, and the associated level of cost.

Table 1: Summary of Transportation Wildlife Mitigation Measures

Measure	Difficulty in Effort and Time to Deployment	Effectiveness at Providing Connectivity	Effectiveness at Reducing WVCs	Use Across U.S.	Cost to Agency
ACTIONS THAT TARGET WILDLIFE					
Retrofit or Modify Existing Infrastructure					
Place fence to existing structures	Moderate	Moderate	High	High	Moderate
Retrofit culverts and bridges to allow wildlife movement through and under	Low	Moderate	Moderate	Moderate	Low
Adapt existing fences and gates to allow wildlife passage through structures rather than block movement	Low to Moderate	Moderate	Moderate	Moderate	Low
Make the Roadside Less Attractive to Wildlife					
Supplemental feeding/salt/water at a distance from road	Low	Low	Unknown	Low	Low
Vegetation management - reduce vegetation, plant unpalatable species in right-of-way	Low	Low	Low to Moderate	Unknown to Moderate	Low
Use road de-icing agents that don't attract wildlife	Low	Moderate	Low to Moderate	Low	Low
Remove roadkill carcasses to avoid attracting eagles, vultures and other scavengers	Low	Moderate	Low to Moderate	Low	Low
Deter Wildlife from Entering the Road					
Place exclusion fence and deterrents at egress and ingress points, do not provide for connectivity	Low	Low	High	High	Moderate
Facilitate Wildlife Movement Across the Road					
Lay down right-of-way fence for seasonal wildlife movement across road	Low	High	Moderate to High	Low	None to Low
Provide Wildlife Crossing Structures and Keep Wildlife Off the Road					
Wildlife crossing structures alone	High	Moderate	Moderate	High	High
Wildlife crossing structures, exclusion fence, fence end treatments, escape ramps, guards (deterrents at entrances to fenced area)	High	High	High	High	High
Provide Escape Mechanisms from Fenced Area					

Measure	Difficulty in Effort and Time to Deployment	Effectiveness at Providing Connectivity	Effectiveness at Reducing WVCs	Use Across U.S.	Cost to Agency
Give wildlife a way to escape road right-of-way (e.g. escape ramps)	Low	Low	Low to Moderate	Moderate	Low
Prevent Wildlife Entrapment					
Use only biodegradable erosion control matting in right-of-way areas post construction	Low	Moderate	Low	Moderate	Low
Reduce Wildlife Numbers					
Increase hunting pressure of deer in areas with high WVCs and low ability to install crossing structures and fences	Low to Moderate	Low	Moderate	Low to Moderate	Low
Experimental, Ineffective, Inconclusive, and Untested Methods Targeting Wildlife					
Visual (e.g. reflectors, painted white lines)	Low	Low	Low	Low	Low
Auditory (e.g. whistles)	Low to Moderate	Low	Inconclusive to Low	Low	Low to Moderate
Olfactory	Low	Low	Inconclusive to Low	Low	Low
Painted White Lines	Low	Low	Low	Low	Low
ACTIONS THAT TARGET DRIVERS					
Public Outreach					
Public awareness campaigns	Moderate	Low	Largely Unknown	High	Low
Signs					
Static driver warning signs and signs with lights	Low	Low	Low	High	Low
Variable message boards	Low	Low	Low to Moderate	High	Low
Speed Reduction Zones					
Wildlife crossing zones	Low to Moderate	Moderate	Low to Moderate	Low	Low
Animal-Detection Driver Warning Systems					
Animal (Wildlife) Activated Detection Systems, no exclusion fence over an area ¼ of a mile or longer, wildlife cross over the road	Moderate to High	Moderate to High	Moderate	Low	High

Measure	Difficulty in Effort and Time to Deployment	Effectiveness at Providing Connectivity	Effectiveness at Reducing WVCs	Use Across U.S.	Cost to Agency
Animal detection system with exclusion fence at a crosswalk that is less than ¼ of a mile wide, or at fence ends, wildlife cross over the road	Moderate to High	Moderate to High	Moderate to High	Low	High
Experimental, Ineffective, Inconclusive, and Untested Methods Targeting Drivers					
Traffic calming	Moderate	Low	Low to Moderate	High	Moderate
Reduce roadside vegetation to improve visibility	Low	Unknown	Unknown to Low	Unknown	Low
Roadside lighting	Moderate	Moderate	Low to Moderate	High	Moderate to High
In-road lighting – solar pucks	Moderate	Unknown	Unknown	Low	Moderate
On-vehicle lighting in addition to standard lighting, light beams directed below the vehicle onto the pavement	Low	Unknown	Unknown	Low	Low
Driver phone applications	Low	Unknown	Unknown	Moderate	Low
In-vehicle warning systems	High	Unknown	Unknown	Low	Low to Moderate
Self-driving vehicles	Low	Unknown	Unknown	Low	Low

Source: Adapted from Cramer et al. 2016 and Cramer et al. 2022.

ACTIONS THAT TARGET WILDLIFE

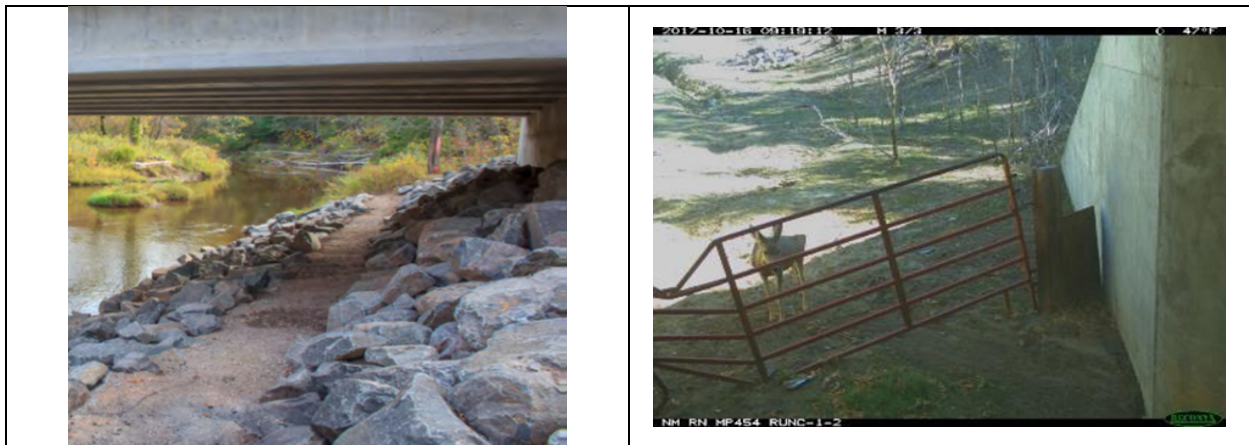
Common transportation mitigation methods that target modifications to wildlife behavior include retrofitting existing road features (bridges, culverts, etc.) for use as wildlife crossing structures, altering roadside habitats to make them less attractive and to deter wildlife from accessing roadways, facilitating wildlife movement across roadways or excluding wildlife from roadways, providing ways for wildlife to escape when trapped on a road, and attempting to prevent entrapment. Less common or effective wildlife-targeted mitigation methods include management of roadside vegetation, use of devices (such as tags or whistles) to elicit behavioral response, reflectors and noise deterrents, olfactory deterrents, and painted white lines (e.g. painted to resemble cattle guards).

Retrofit Infrastructure

Retrofitting existing roadway infrastructure, such as culverts and bridges, to make them suitable for wildlife crossings is one of the most low-cost and low-effort mitigation methods (Smith et al. 2015; U.S. Forest Service 2017). Target species' life history strategies and the characteristics of existing structures should be carefully considered, however; not all existing structures have the potential to be suitable for target species (Kintsch and Cramer 2011; Smith et al. 2015; U.S. Forest Service 2017). The Washington DOT Passage Assessment System provides information on how

to evaluate existing infrastructure for potential retrofitting for all taxa of wildlife (Kintsch and Cramer 2011). Suggested retrofits include fence placement adjacent to existing structures to encourage wildlife usage of the structure (Gagnon et al. 2015); retrofit of culverts and areas under bridges to encourage wildlife movement, including fence placement to the structure and clearing vegetation to facilitate movement; adapting fences and gates to facilitate wildlife movement; and adapting fencing to facilitate wildlife movement across the road. These retrofits are presented in greater detail below (**Figure 1**).

Figure 1: Examples of retrofitted infrastructure. (Left: Minnesota passage bench cleared within rip rap provide wildlife and human passage; Right: deer and other wildlife are often prevented from using culverts when livestock gates are placed at the entrances to restrict cattle access. Removal of the gates allows wildlife to use the structures, as was the case with this gate in New Mexico).



Source: Left – P. Leete; Right - Arizona Game and Fish Department; New Mexico DOT.

Methods such as the installation of fish ladders or dry shelves can improve the suitability of existing culverts for fish passage (Kozarek and Hernick 2024; U.S. Forest Service 2017) or terrestrial animals, respectively (U.S. Forest Service 2017). Likewise, strategically placed boulders, downed tree logs, stumps, or ramps can improve accessibility to underpasses and overpasses for terrestrial animals (KCal News 2021).

Existing fences and gates can also be retrofitted to allow wildlife movement beneath the road. Fencing and gate adaptation methods include adjusting fence height, length, materials, or orientation to allow wildlife to access infrastructure in order to move beneath the road and should be matched to the needs of the target species (Huijser et al. 2016; Markle and Stapleton 2022). There are several state wildlife agency guidelines to assist with exact fence placement, heights, and materials (Paige 2008; Paige 2016; Paige 2025). Fences at wildlife crossing structures that keep livestock out should be at least 18 inches off the ground and made of rails; this allows adult ungulates to jump over and the young to crawl underneath, while also allowing for other types of smaller wildlife permeability (**Figure 2**). These fences also serve to keep cattle from entering the crossing structure area (Paige 2025). Likewise, human use of existing structures, especially off-road motorized vehicles, can deter wildlife from using existing structures. Arizona and other states have placed rail fence across structures in order to prevent easy vehicle access.

Figure 2: Examples of rail fencing used at wildlife crossing structures. (Left: wildlife-friendly rail fence placed a distance from the entrance of wildlife crossing structures in Utah to allow wildlife permeability while keeping cattle out. Right: Arizona DOT placed a steel rail fence at a wildlife underpass structure to allow wildlife access but deter motorized vehicle use).



Source: Left – P. Cramer; Right – Arizona Game and Fish Department.

Make Roadsides Less Attractive for Wildlife

Roadway ROWs often provide attractive foraging habitat for various species (Gamo et al. 2023; Jacobson 2005; MDC 2024; Rea 2003) due to the presence of roadside vegetation, de-icing agents that contain important minerals, animal carcasses that attract scavengers, and nearby water resources. Vegetation management, such as mowing, is a mitigation method often used to reduce the volume and attractiveness of available forage along roadways (Gamo et al. 2023; Gray 2009; Wildlife Roadsharing Resource Centre [WRRC] 2025); however, Normandeau Associates, Inc. (2012) could not find a relationship between changes in deer-vehicle collisions and mowing regimes in a study that examined 10 locations in New York and Maryland. Other studies demonstrated mixed results of the effectiveness of vegetation management as a transportation mitigation method (Rea 2003; WRRC 2025). Additionally, mowing and pruning of roadside vegetation may increase the attractiveness of foraging opportunities along roadsides (Rea 2003; WRRC 2025).

Minerals within the deicing materials used on roadways are also known to attract ungulates. Wildlife managers have found that ungulates can be redirected away from roads by providing supplemental feeding, also called intercept feeding, at strategic locations farther from roadways (Grosman et al. 2011; Normandeau Associates, Inc. 2012; Wood and Wolfe 1988). Carcasses of wildlife killed along roads should be removed promptly to avoid attracting eagles and other scavengers (Grubb et al. 2018). Water can also be a potential attractant, enticing animals to cross roadways. In dryer locations where water is a critical resource, animals can be deterred from crossing the road by the placement of water resources, such as water guzzlers or catchments, away from the road (Nielsen 2020).

Deter Wildlife from Entering the Road

The method most often used in the United States to reduce WVCs is to erect wildlife exclusion fences, guiding wildlife specific locations where they can cross over or under the road (**Figure 3**). Fencing, used in combination with retrofitted roadway infrastructure, new wildlife crossing

structures, or other WVC mitigation strategies, can improve rates of wildlife crossing usage by directing animals to the structures, thereby lowering WVC incidents (Animal Road Crossing [ARC] Solutions 2017; Brennan et al. 2022; Gagnon et al. 2018; Huijser et al. 2016). Fencing characteristics such as length, height, material, and anticipated frequency of maintenance are important considerations in overall effectiveness (Gagnon et al. 2018; Huijser et al. 2016). Shorter fence lengths along road segments (less than or equal to 0.5 kilometers) have been shown to reduce the effectiveness of mitigation measures implemented for large mammals (Huijser et al. 2016). Opaque fencing is better for some reptile species, such as tortoises, which have been shown to continually try to move through fences they can see past (Ballesterio et al. 2023). Likewise, fence height should be tailored to target species climbing abilities (Woltz et al. 2008). Poorly maintained fencing can allow wildlife access to roadways in inappropriate locations, potentially increasing risk of WVCs (Baxter-Gilbert et al. 2015), thus maintenance considerations are important when planning and installing fences. Wild ungulate exclusion fence is typically 8 feet tall, supported by metal or wooden fence posts, and placed along the ROW fence line.

Figure 3: Wildlife exclusion fencing used to guide wildlife to crossing structures. (Left: 8-foot-high wildlife exclusion fences at the US 160 Chimney Rock overpass in Colorado. Right: mule deer use a wildlife underpass under US 191 in Utah. Note the wildlife friendly rail fence at the far end of the structure).



Source: Left – Colorado DOT, Southern Ute Indian Tribe, and Wildlife Connectivity Institute; Right – Utah DOT and P. Cramer.

Fence end treatments can enhance the effectiveness of fencing by discouraging wildlife from crossing roads at fence ends (Huijser et al. 2015; Huijser et al. 2016). Treatments include angling the end of the fence toward the road, installing cattle guards at fence ends, utilizing additional deterrents in combination, tying fence ends into structures or steep slopes, and blocking access to the ROW through other methods, such as boulder fields (Huijser et al. 2015; Huijser et al. 2016). Fence end treatments should be tailored to life history strategies and preferences of target species. Some amphibian species, for example, have been shown to be deterred from moving past fence ends with horizontal v-shaped inward angled fence end treatments that direct the animals moving along the fence to take a U-turn and move back toward the fenced area (**Figure 4**) (Harman et al. 2023).

Figure 4: Example showing a v-shaped fence-end treatment used to evaluate effectiveness for amphibians.



Source: Harman et al. 2023

While fencing can be an important factor in excluding wildlife from attempting roadway crossings in all but designated areas, it should not be used as a lone method of transportation mitigation, as solitary fencing can serve to increase the barrier effect of roads and result in wildlife mortalities due to lack of access to crucial resources like water, food, winter habitat, and escape from fire, flooding, and human activities (ARC Solutions 2017; Huijser et al. 2008; Gagnon et al. 2018)

The egress and ingress portions of exclusion fenced areas also require deterrents, such as double cattle guards and wildlife guards, to keep wildlife from moving into the fenced area of the road (**Figure 5**). When used for wildlife, standard cattle guards are doubled or consist of single cattle guards paired with electric pavement or electric pavement alone. The single cattle guards typically used for livestock are not sufficient for wild ungulates and carnivores, as they can jump over or walk across these types of flat bar deterrents. By comparison, round bar cattle guards make it very difficult for animals to walk across. In Colorado, Kintsch et al. 2021 found round barred guards repelled mule deer 91 percent of the time, while flat barred guards repelled the deer 84 percent of the time. In Utah, Cramer and Flower (2017) found double cattle guards to be 85 to 90 percent successful in deterring mule deer, which was more successful than any other guard tested. Newly developing technologies such as electric pavement are proving promising; Cramer and Hamlin (2024) found that electric pavement paired with a single cattle guard was 59 percent successful in deterring mule deer from entering a highway. This technology is still being developed, however, as electric pavement does pose maintenance issues when snow accumulates on the pad, effectively insulating animals from the electricity below.

Figure 5: Various types of cattle guards used to deter wildlife from entering roadways. (Top photos: Flat (left) and round (right) bar guards were placed and studied on State Highway 9 in Colorado. The round bar guards were more successful in deterring mule deer, but also more dangerous for animals that placed their feet on them, as well as for motorcyclists. Bottom left: two wildlife guards used to repel mule deer in Utah. Bottom right: electric pavement pad placed in front of a single cattle guard to repel in Colorado).



Source: Top photos - Colorado Dept. Of Transportation, Colorado Parks and Wildlife, ECO-resolutions, and P. Cramer; Bottom left - P. Cramer and Utah Division of Wildlife Resources; Bottom right - Colorado Department of Transportation, Colorado Parks and Wildlife, Wildlife Connectivity Institute.

Different types of exclusion fencing are used for amphibians and reptiles than for ungulates and other large mammals (**Figure 6**). Woven wire mesh fences are placed to guide smaller reptiles and amphibians to crossing structures. Plastic drift fencing, concrete walls, and half pipe barrier walls can be installed to guide animals to structures.

Figure 6: Examples of small species fencing structures. (Top left: a plastic drift fence for smaller species, Top right: a 3-foot concrete wall in Florida. Bottom left: plastic woven mesh netting served as a fence for small animals. Bottom right: a half arch of plastic piping for reptiles and amphibians).



Source: Top left - Arizona Game and Fish Department.; Top right - P. Cramer; Bottom left - Zarete, New Jersey Division of Fish and Wildlife 2019; Bottom right - Heaven et al. 2019.

ROW modifications can also help to limit small animal wildlife access to roadways. Wildlife can be deterred by increasing the grade of a sloped embankment and adding rip rap to help block access to roadways (Ballesterio et al. 2023).

Facilitate Wildlife Movement Across the Road

In certain locations where wildlife movements across roads are predictable, such as locations where roads intersect regular wildlife movements and where traffic volumes are well below 2,000 AADT during the period of wildlife movement, specific mitigation methods may be appropriate to facilitate wildlife connectivity and reduce the risk of wildlife lingering in the road (Cramer et al. 2022). These approaches include laying down ROW fencing during certain periods, temporary road closures, reducing speed limits during certain periods, and other actions. These methods alone may not reduce WVCs without additional mitigation methods giving notice to drivers through strategies such as the use of temporary dynamic signs or variable message boards, which are discussed further in the **Actions That Target Drivers** section below.

Laying down ROW fences during periods when wildlife populations need to cross facilitates quicker ungulate movements across roads (Cramer et al. 2022, **Figure 7**). These types of fences are more common in the western U.S. where public land agencies and The Nature Conservancy

own land. In New Mexico, for example, the BLM lays down ROW fences along U.S. 285 on the Rio Grande Del Norte National Monument during spring and fall migration periods (Cramer et al. 2022).

Figure 7: Laydown ROW fences along U.S. 285 in the Rio Grande Del Norte National Monument, New Mexico.



Source: Cramer et al. 2022.

Provide Wildlife Crossings Structures and Keep Wildlife Off the Road

A wide variety of wildlife crossing structures can be used to keep wildlife from entering the roadway. Selection of wildlife crossing structure size and type is dictated by the target species (**Table 2**).

Table 2: Functional Classes of Transportation Culverts and Bridges and General Wildlife Use

Structure Size Class	Example Dimensions	Structure Types	Species Known to Utilize the Structure Type
Small Underpass Structure¹	≤1.5 meters (5 feet) span by ≥1.5 meters (5 feet) high	Pipe, box and arch culverts	Amphibians, small mammals
Medium² Underpass Structure	>1.5 meters (5 feet) to 2.4 meters (8 foot) span by >1.5 meters (5 feet) to 2.4 meters (8 feet) high	Box and arch culverts, small bridges	Coyote, bobcat, black bear, porcupine, raccoon, fox
Large Underpass Structure³	≥3.1 meters (10 feet) span by ≥ 3.1 meters (10 feet) high. OR Lower and Wider: ≥6.1 meters (20 feet) span by ≥2.4 meters (8 feet) high.	Bridges and large box or arch culverts (<i>note</i> , structures with multiple chambers are considered as individual units)	Deer, elk, black bear, and all species that use smaller underpasses
Viaduct⁴	Typically, ≥ 6.1 meters (20 feet) high over multiple spans (e.g., ≥120 foot total span).	Bridges extending over multiple spans	Most wildlife, including wary species
Wildlife Overpass⁵	Typically, 40-50 meters wide for multi-species crossings; may be narrower in some cases.	Overpass structure above road with soil cover; may have plant growth	Most wildlife, including birds
Specialized Culverts⁶	Current designs are small culverts less than 0.5 meters (24 inch) span, could also include larger structures	Culverts	Reptiles and amphibians
Canopy Bridges⁷	The length is approximately the width of two-lane roads plus shoulder and right-of-way width	Ropes fashioned as a matrix of intertwined netting, connected to trees or platforms across the road area	Flying squirrels, arboreal rodents

¹New Jersey Division of Fish and Wildlife 2019; Ontario Ministry of Transportation 2017.

²Cramer and Hamlin 2019; Cramer and Hamlin 2020; Cramer 2014; Kintsch et al. 2021.

³Kintsch et al. 2021; Cramer and Hamlin 2024a; Loberger et al. 2021; Cramer and Hamlin 2017; Cramer 2012; Cramer 2014; Cramer and Hamlin 2019; Cramer and Hamlin 2020; Dodd et al. 2012.

⁴Loberger et al. 2021; Gagnon et al. 2017.

⁵Kintsch et al. 2021; Cramer and Hamlin 2024b; Gagnon et al. 2014; Gagnon et al. 2017.

⁶Gunson et al. 2016.

⁷Kintsch and Cramer 2011.

The types of structures identified in **Table 2** are represented in the photos below. These are just brief examples of the types of structures available in each structure category. The majority of examples are selected to represent species in Missouri (**Figure 8**, **Figure 9**, **Figure 10**).

Figure 8: Small underpass structures. (Top left: a raccoon utilizing a small mammal shelf through a culvert in Montana. Top right: toadlets enter a crossing structure. Bottom left: a Blanding's turtle underpass with a sky light in Massachusetts. Bottom right: a salamander underpass in Vermont).



Source: Top left - P. Cramer and Montana DOT; Top right - L. Sielicki FWCP; Bottom photos - P. Cramer.

Figure 9: Medium to large underpass structures. (Top left: river otters using an arched underpass in Colorado. Top right: white-tailed deer used a long steel culvert under US 93 in Montana. Bottom left: sandhill cranes repeatedly took their colt through a wet bottom concrete box culvert under US 93 in Montana. Bottom right: white-tailed deer utilizing wildlife crossing bridges under 5 feet high).



Source: Top left - Colorado Department of Transportation, Colorado Parks and Wildlife, ECO-resolutions, and P. Cramer; Top right and bottom photos - Montana DOT and P. Cramer.

Figure 10: Overpass structures. (Top left: mule deer moving over the U.S.'s first wildlife overpass over IS-15 in Utah. Top right: a herd of bull elk moving over the IS-15 overpass. Bottom left mule deer herds moving over the US 160 Chimney Rock overpass in Colorado. Bottom right: a young black bear moving over the US-160 overpass).



Source: Top photos - Utah DOT and P. Cramer; Bottom photos - Colorado DOT, Southern Ute Indian Tribe, and Wildlife Connectivity Institute.

Escape Mechanisms and Preventing Wildlife Entrapment

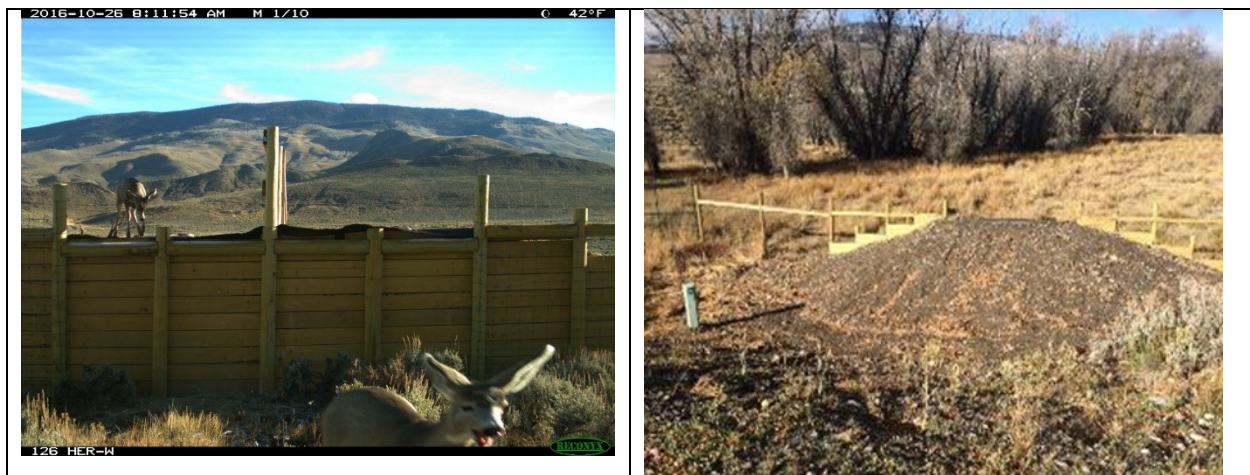
An important facet of transportation mitigation methods, particularly when fencing or other types of physical barriers are used, is the prevention of entrapment by providing wildlife a way to escape roadways if trapped by circumvented or broken fences. Fencing and other physical barriers should include escape ramps (also known as jump-outs) or other escape mechanisms (Clevenger and Huijser 2011; Huijser et al. 2008; Huijser et al. 2015). The number of escape mechanisms installed, as well as their locations and specifications, should be based on target species' life history and the surrounding topographic and habitat characteristics (Jaeger and Fahrig 2004).

Exclusion fencing is often used in combination with escape ramps to allow wildlife to “jump-out” of the ROW if they become trapped in the wildlife exclusion fence area. In Utah and Colorado, the design manuals instruct that there should be a minimum of four escape ramps per mile. Ramps are typically placed near fence ends, driveways and road entrances where wildlife could possibly access the fenced area, and places where wildlife may prefer to move, such as along vegetated areas.

Strategically placed earthen escape ramps can provide wildlife with a means to escape roadways quickly (Arizona DOT n.d.; Clevenger and Huijser 2011; Hammer 2001; **Figure 11**). Escape

ramps provide built-up mounds of earth for wildlife to access the top of the fence from the road side of the fenced ROW and jump down to the wild side of the fence. The walls of the escape ramp on the wild side of the fence should be smooth to prevent animals from accessing the fenced area of the ROW (Arizona DOT n.d.; Clevenger and Huijser 2011; Huijser and Getty 2023). The landing surface should consist of loose dirt or a similar soft surface to prevent injury, and the exit point of the ramps should provide suitable cover for target species (Arizona DOT n.d.; Clevenger and Huijser 2011). Escape ramps without a center line fence perpendicular to the top have been found to be more effective at intercepting animals and have a greater proportion of successful escapes than those with fences (Kintsch et al. 2021, Cramer and Hamlin 2019). The more gradual the slope of the escape ramp, the more likely wildlife will be intercepted by them and move to the top to escape (Kintsch et al. 2021); 3:1 or even 4:1 slopes are recommended in Colorado and Arizona. There are various alternative escape ramp designs used in Utah and Colorado that are also proving to be effective (Cramer and Hamlin 2024a).

Figure 11: Escape ramps. (Left: mule deer using an escape ramp in Colorado. Right: the most effective escape ramp design in the Colorado SR 9 study by Kintsch et al. 2021 was the 3:1 slope with no wildlife fence in the middle).



Source: Left - Colorado DOT, Colorado Parks and Wildlife, ECO-resolutions, and P. Cramer; Right – P. Cramer

Roadway design and construction can also pose a risk of entrapment for wildlife (**Figure 11, Figure 12**). Curbs can effectively trap smaller wildlife on roadways if the curb height is too tall (Ballesterio et al. 2023; Minnesota DNR 2008). Modified curbs or the conversion of curbs to ditches can help reduce the risk of becoming trapped (Ballesterio et al. 2023; Leete 2014; Minnesota DNR 2008).

Figure 12: Curb (right photo) and grates (left photo), rather than gutter designs, can help prevent small animals from becoming trapped in the road or from falling into water filled vaults below the road.



Source: Left – P. Leete; Right – P. Cramer.

During construction of wildlife crossing structures, care should also be taken to avoid trapping wildlife on roadways. Fencing should not be installed until the crossing structure is complete (Seidler et al. 2018). Likewise, only biodegradable erosion control matting should be used during roadway construction to minimize the risk of wildlife entrapment (Leete 2014; USDA NRCS 2013; USFWS n.d.).

Figure 13: A snake trapped in plastic erosion control netting.



Source: P. Leete.

Experimental, Ineffective, and Inconclusive Methods

Less intensive, but often inconclusive and/or ineffective, transportation mitigation methods when compared to those discussed above include visual (such as wildlife warning reflectors or white painted lines), auditory (such as whistles), and olfactory deterrents to discourage animals from accessing roadways.

Wildlife warning reflectors are positioned along the edges of roads in an orientation such that they will reflect the headlights of passing vehicles onto the roadside in order to deter animals near the road from crossing (Benten et al. 2018a; Riginos et al. 2018). Studies on the effectiveness of wildlife warning reflectors as a method for reducing WVCs are inconclusive, with some studies reporting moderately successful results and others reporting no discernable changes in WVC rates (Benten et al. 2018a; Brieger et al. 2016; D'Angelo and van der Ree 2015; Gagnon et al. 2023; Riginos et al. 2018; Waring et al. 1991). Discrepancies in study conclusions have been linked to variable study designs, differing reflector models, and fluctuations in animal activity at specific locations during the study period (Benten et al. 2018b; Brieger et al. 2016; Gagnon et al. 2023; Riginos et al. 2018). Evidence that deer may become habituated to the warning reflectors has also been seen in some studies (Riginos et al. 2018).

Another visual deterrence method shown to be ineffective in preventing roadway access and WVCs is the painting of white lines across the road to mimic cattle guards (Cramer et al. 2014). A wildlife crossing study in Utah determined that wildlife were not deterred by the white lines and continued to access the roadway (Cramer et al. 2014).

Roadway noise can act as a deterrent for certain wildlife species, especially in areas with heavy traffic volumes (Shilling et al. 2018). Individual species' tolerance to noise varies, and can lead to habitat fragmentation, migration disruption, and population impacts for noise-sensitive species (Laurance 2015; Shilling et al. 2018). Because roadway noise can act as a barrier to wildlife, experiments with various noise-based WVC mitigation methods have been attempted to determine if noise deterrents are a viable WVC reduction method. Noise deterrents, such as whistles or systems that mimic animal warning calls, are mounted on the front of vehicles and emit audio signals to discourage animals from entering the roadways as the vehicle passes (D'Angelo and van der Ree 2015; Scheifele et al. 2003; Valitzski et al. 2009). Whistles and other auditory deterrents have been largely shown to be ineffective at reducing WVCs due to sound attenuation, environmental and topographic factors that limit the distance sound can carry, and incorrect decibel emissions for target species (D'Angelo and van der Ree 2015; Scheifele et al. 2003; Valitzski et al. 2009).

Olfactory deterrence methods have also been utilized as a lower-maintenance mitigation option. As with auditory deterrence methods, olfactory-based methods have had mixed success. Some studies reported a short-term decrease in WVCs after olfactory repellents were placed in WVC hotspots (Bil et al. 2017; Bil et al. 2019; Bil et al. 2024); however, reports of wildlife habituation to the repellents, as well as other variables influencing study results such as traffic volume, weather, target species, short length of time scents last on the landscape, and type of repellent, makes the overall effectiveness of olfactory methods inconclusive when applied to a broader scale and wider range of species and situations (Bil et al. 2020; Bil et al. 2024; Elmeros et al. 2011; Keken et al. 2024).

ACTIONS TARGETING DRIVERS

Driver-targeted mitigation strategies are aimed at altering driver awareness and behavior, thereby helping to reduce WVCs (Gagnon et al. 2018; Huijser et al. 2009).

Public Education and Awareness

Public awareness campaigns are used to alert the public to increased risk of WVCs either in specific locations, at certain times of year, or both. The campaigns can also warn drivers of countermeasures being implemented in a location that could reduce WVCs. Information on the campaigns is typically released to the media and placed on social media accounts to alert the public.

Signage

Signage is often used as a low-cost cautionary action to alert drivers to the potential of wildlife in the road. The ubiquitous yellow diamond signs showing the silhouette of a deer may help in the short term (Found and Boyce 2011) but are generally recognized as having no long-term effect on driver caution and speed reduction (Bond and Jones 2023). The addition of flashing lights and animation to signs attracts driver attention better than static signs and may help to reduce motorists' speeds; however, their effect at reducing WVCs remains moderate to ineffective (Pojar et al. 1975; Sullivan et al. 2004). If signs are placed only seasonally, it may help to increase driver alertness in certain areas (Sullivan et al. 2004).

Variable message boards are electronic signs typically mounted on wheeled trailers and are much larger than static signs on posts. They are typically used only seasonally in specific areas where animals are known to cross or linger in the road or ROW. Recent research by Donaldson and Kweon (2019) indicated deer carcass removals were significantly lower and motorist speeds were reduced when variable message boards were present. Variable message boards may provide a temporary option to potentially reduce collisions; however, additional research to corroborate their effectiveness is warranted.

Speed Reduction Zones

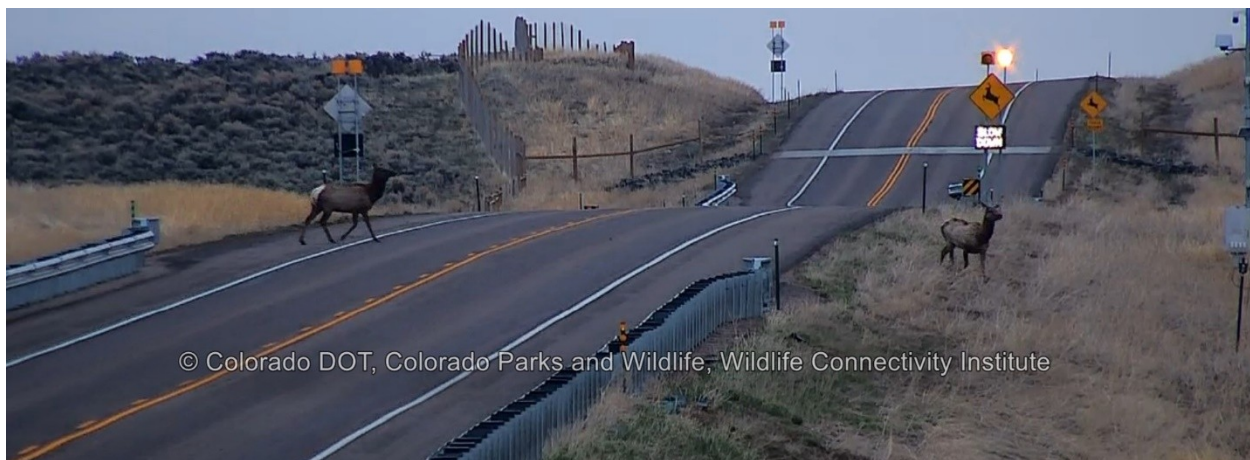
Speed reduction zones aim to reduce motorists' speed in specific locations where wildlife are often in or near the roadway. Speed reduction zones can be implemented during specific times, seasonally, or on a year-round basis. Hourly-based speed reduction zones are often activated during night-time hours. Seasonal signs can be placed temporarily during the season of concern or can include variable message boards. A study in Colorado reviewed the effectiveness of speed reduction zones, showing inconclusive results on the overall reduction of WVCs. The study determined that in order for speed reduction zones to achieve a notable reduction in WVCs, speed limits would need to be 45 miles per hour or less (Nichols et al. 2014).

Wildlife Detection Driver Warning Systems

Wildlife-detection driver warning systems (WDS) use technologies such as radar, thermal imaging, LiDAR (remote sensing), and computer algorithms to detect animals in the ROW and roadway and subsequently activate driver warning signs (**Figure 14**). WDS systems have preprogrammed conditions that must be met to activate driver warning signs, such as a large animal in the ROW (Gagnon et al. 2018; Huijser et al. 2009). WDS systems should only be considered for two-lane roads with traffic volumes well under 10,000 AADT, and should only be used over a limited area, such as a wildlife crosswalk of less than 100 feet or a stretch of road no greater than 0.5 miles long where wildlife are expected to cross (Gagnon et al. 2018; Gordon et al. 2004).

Current research in Colorado is examining the feasibility of using radar solely to detect animals and activate the WDS (Cramer and Hamlin 2024a); while radar holds promise for detecting wildlife at greater distances than thermal imaging cameras, it cannot detect size of the animals unless they are moving. The system is under study at this time and should be considered experimental. Research on a thermal image camera system in Utah shows that the mule deer moving through a 60-foot-wide wildlife crosswalk are better detected by the WDS, and that the research cameras activate for night movements more consistently when the cameras can detect system lights (Cramer and Hamlin 2025).

Figure 14: The WDS activating to warn drivers of the presence of elk crossing Colorado's State Highway 13, north of Craig.



Source: Cramer and Hamlin. 2024a.

Experimental, Ineffective, and Inconclusive Methods

Other experimental, ineffective, and/or inconclusive mitigation methods that have been attempted to influence driver behavior include traffic calming; wildlife crosswalks; roadside, in-road, and on-vehicle lighting; driver phone applications; in-vehicle warning systems; and self-driving vehicles.

Traffic calming methods are used to further reduce driver speeds. Methods such as speed bumps, rumble strips, and slow points have been implemented on highways in locations where wildlife crossings are expected (WRRRC 2025). Although traffic calming may be successfully utilized in urban areas, maintenance costs, particularly due to the effects of winter weather, may be prohibitive. Additionally, many traffic calming methods are not safe to use on roads with higher speed limits (Huijser et al. 2007; WRRRC 2025).

Management of roadside vegetation is used to increase visibility surrounding roadways (Gamo et al. 2023; Gray 2009; WRRRC 2025). Studies have shown mixed results of the effectiveness of vegetation management as a transportation mitigation method (Rea 2003; WRRRC 2025); increased visibility along roadways has been shown to increase driver speeds, which may ultimately lead to an increase in WVCs (Rea 2003; WRRRC 2025).

Wildlife crosswalks typically consist of mitigation measures (such as fencing) to direct wildlife to specific crossing locations that are clearly marked to attract motorist attention (Lehnert and Bissonette 1997). Issues noted with this transportation mitigation method include motorist

habituation to signage and difficulty keeping wildlife inside the designated crosswalk areas (Lehnert and Bissonette 1997). Current research in Utah is documenting driver responses to WDS light activation in a 60 feet wide crosswalk in wildlife exclusion fence. Drivers slowed down only 2.8 miles per hour on average when lights were activated, and their average speed after slowing down was still above the posted speed limit of 55 miles per hour (Cramer and Hamlin 2025). Thus, the human factors related to these approaches still need to be addressed.

Various configurations of lighting changes have been attempted in order to improve the visibility of wildlife to motorists in dark or otherwise limited-visibility conditions. The effectiveness of roadside lighting reducing WVCs has been inconclusive. While reductions in WVCs have been observed in areas with roadside lighting (Huijser et al. 2021; Putman and Langbein 2024), it is unclear if the reason for the reductions is better visibility, or if wildlife are avoiding crossing in lit areas (Huijser et al. 2021). Additionally, roadway lighting is not a feasible method for reducing WVCs on smaller or rural road networks, due to the maintenance cost (Huijser et al. 2021; Putman and Langbein 2024). Species life history can also impact the effectiveness of roadway lighting as a mitigation method, as some species may be attracted to light, putting them at higher risk of WVCs. Likewise, if target species exhibit avoidance of light, roadway lighting could further exacerbate the barrier effect of roads and subsequent habitat fragmentation (Huijser et al. 2021; Putman and Langbein 2024).

Phone applications have been used as a method to alert drivers to real-time road conditions through applications such as WAZE. These applications can be used by DOTs to send public alerts for specific road segments and/or during time periods of frequent wildlife movements, such as migration seasons, or to allow drivers to notify each other of live or dead wildlife in the roadway (Cramer et al. 2022). Virginia DOT has experimented with using WAZE to alert drivers as well as to collect deer carcass data (Donaldson 2017); however, minimal study has been done to determine if these types of driver warning systems are effective at reducing WVCs.

Other driver warning systems that have been introduced recently include infrared wildlife detection built into vehicles. These systems warn drivers when wildlife is detected in the road, and some models may also apply the brakes automatically. Volvo has developed the Volvo Pilot Assist II project that detects large wildlife in the road from up to 656 feet away through radar and other camera components. When wildlife are detected, the Volvo Pilot Assist II alerts the driver through a loud warning and flashing lights on the dashboard. Because these detection systems are relatively new, minimal study has been done to determine their overall efficiency at reducing WVCs (Cramer et al. 2022).

Driverless vehicles are also being developed with onboard warning systems, which also typically use infrared cameras to see wildlife. Little to no research has been conducted to gauge their efficacy, but it is expected that in the coming years these will be standard features in vehicles.

State Wildlife Connectivity and Corridor Action Plans

Wildlife Connectivity Action Plans are typically research-based plans that assess both the potential for wildlife-vehicle conflict and needs of wildlife to move across the landscape in order to include the consideration of wildlife in transportation planning. These plans can also be known as State Wildlife and Transportation Plans (Massachusetts); State Transportation and Wildlife

Plans (FHWA-developed guidelines for any state to follow); Wildlife Corridor Action Plans (New Mexico); Habitat Connectivity Action Plans (Washington); Statewide Wildlife Crossings Prioritization Study (Nevada); and various other titles involving wildlife, connectivity, and potentially wildlife-vehicle collisions or conflict.

There are several levels of information in these Action Plans. The first and most consistently used level is to assess reported wildlife-vehicle collisions with an ArcGIS Optimized Hot Spot Analysis, using the Getis-Ord GI* Statistic or in earlier plans, Kernel Density Analysis or Evaluation. The second level is to add the incorporation of wildlife habitat and movement information available from state wildlife agencies to the hot spot analysis to look at transportation safety (the crash modeling) and ecological connectivity together. The third level is to incorporate the first two levels plus connectivity modeling maps that look at either species or ecosystem connectivity (or both) across roads or even the entire state (such as Washington's Habitat Connectivity Action Plan).

Three state wildlife connectivity Action Plans were reviewed to provide an understanding of important factors to be considered for Action Plan development, as well as how other states have incorporated these factors within their Action Plans and the associated costs (**Table 3**). The reviewed Action Plans included the New Mexico Wildlife Corridors Action Plan, the Washington State Habitat Connectivity Action Plan, and the Nevada DOT Wildlife Crossings Prioritization Study.

The New Mexico Wildlife Corridors Action Plan was developed with scientific research on hot spot modeling, wildlife movement telemetry data, wildlife movement modeling, and field visits (Cramer et al. 2022). This plan was among the first in-depth studies to treat the wildlife-vehicle conflict as an overall landscape challenge, and to identify where wildlife needs to move regardless of roads. It used wildlife telemetry data not only from the New Mexico Fish and Game Department, but also from several Tribal nation wildlife studies, and academic studies of wildlife movement. Once modeling was complete, the team assessed top areas based on multiple factors in a spreadsheet. They then field assessed the top 20 locations where both crash hot spot modeling and wildlife movement modeling indicated top priorities for wildlife mitigation. Two Tribes won FHWA Wildlife Crossings Pilot Program funding for studies to design future wildlife crossing mitigation in their top Action Plan areas, and the state legislature allocated \$50 million to address these areas.

The Washington State Habitat Connectivity Action Plan was completed in 2025 and involved many factors and data layers to examine landscape connectivity across the state and the areas where connectivity needs to be restored across Washington DOT. The plan was funded by the Washington Department of Fish and Wildlife and was completed in conjunction with Washington State DOT, the non-profit Conservation Northwest, and three research-based scientific consulting companies: TerrAdapt, Conservation Biology Institute, and Wildlife Connectivity Institute.

The Nevada DOT Wildlife Crossings Prioritization Study (Jones et al. 2025) was developed to meet the requirements of Assembly Bill No. 112 (AB112), which directed Nevada DOT to "prioritize areas to implement projects for wildlife crossings or other related highway features to improve permeability for wildlife while maintaining highway user safety." The study was a collaborative effort between Nevada DOT's project team and the Nevada Department of Wildlife, as well as federal, state, local, and tribal land or resource management entities from across the

state of Nevada. The project team's first steps were to identify a suite of focal species and collect relevant spatial data that represented wildlife connectivity and habitat use on a statewide scale. The Nevada DOT project team facilitated an agency partner workshop and a series of project team working sessions to develop a suite of 24 prioritization criteria. Each criterion was assigned to one of the following categories: 1) wildlife vehicle conflict, 2) wildlife movement, 3) big game habitat, 4) special status species habitat, and 5) ecological systems. Both the categories and the individual criteria were weighted based on their relative importance in predicting locations of wildlife conflict or interaction with Nevada DOT-operated roadways. The resulting model created a statewide Prioritization Surface which was used to rank segments of the Nevada DOT-operated highways. The Top 30 segments through this process represent the highest near-term wildlife crossing priorities for Nevada DOT. This list of 30 segments was further refined by considering land security, feasibility, climate resiliency, and Nevada DOT project planning. In addition to the statewide multi-species priorities identified in the Top 30, the project team has identified areas of concern for both WVCs and connectivity of MoDOT focal species.

Table 3: Factors used in three state wildlife connectivity Action Plans.

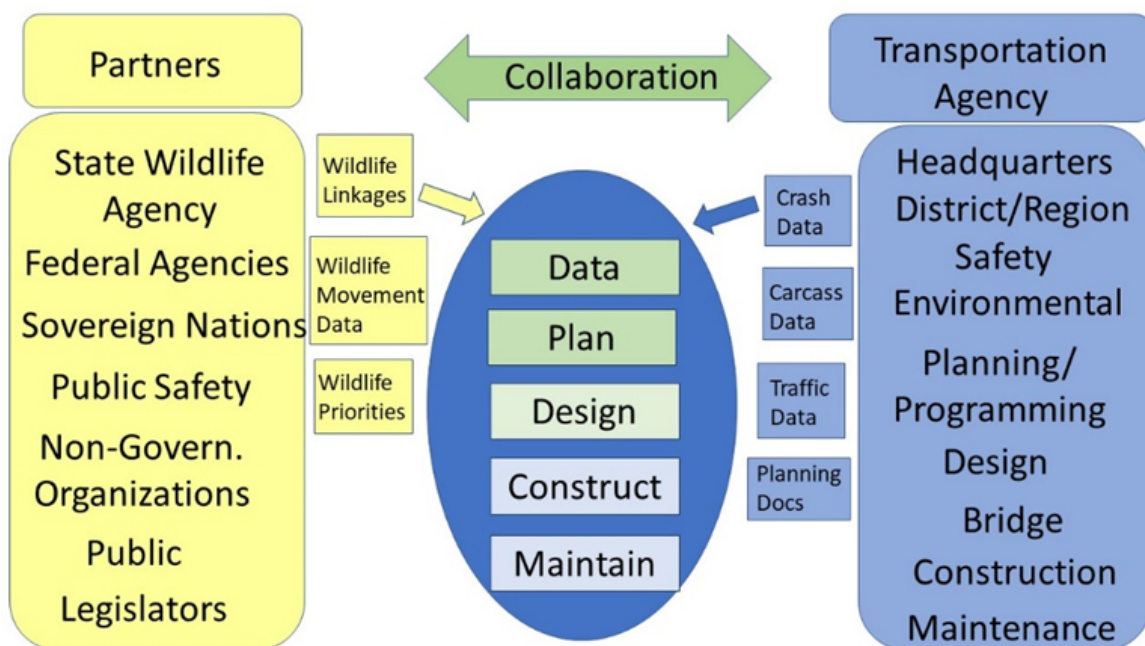
Factor	New Mexico	Washington State	Nevada
Agency sponsor	New Mexico Department of Transportation.	Washington Department of Fish and Wildlife.	Nevada Department of Transportation.
ArcGIS Optimized Hot Spot Analysis modeling of reported crashes with wildlife	Conducted.	Conducted.	Conducted.
Wildlife habitat maps	Included 22 species of concern, potential habitat maps, and 6 large mammals target species habitat maps (mule deer, elk, pronghorn bighorn sheep, puma, black bear).	Included 83 species of concern, potential and known habitat maps.	Included 9 focal species or species groups and 24 unique criteria represented by statewide or range-wide spatial data.
Empirical telemetry data	Included New Mexico Department of Game and Fish data on ungulates, and Tribal and Academic studies on these species and puma.	Included empirical data of dozens of species included in the 83 species maps.	Telemetry data not directly incorporated at statewide scale due to lack of sufficient coverage. But range maps and habitat suitability models informed by telemetry were included.
Wildlife movement model(s)	Included Unicore model of ungulate species and puma and black bear models where these species would cross roads.	Included multiple TerrAdapt created models and past movement models for puma and beaver habitat along streams, etc.	Included habitat connectivity models for pygmy rabbit and Mojave Desert tortoise and mapped migration corridors for pronghorn, mule deer, and bighorn sheep.
Ecosystem models	None.	Included four major ecosystems in Washington, and special areas.	Included spatial data representing ecological landscape connectivity, riparian corridors, and sagebrush habitat quality.
Climate Change models	Climate change models were developed as part of this project and these	Used previous climate change models to look for ecosystem connectivity in	Incorporated a statewide species-agnostic climate model as a secondary

Factor	New Mexico	Washington State	Nevada
	ecosystem changes were factored into prioritization for locations to help species move in response to these changes.	the face of climate change and wildlife movements.	implementation criterion. This model identified areas at statewide and segment scales where wildlife connectivity is anticipated to be preserved into the future.
Interactive portal with maps	Maps used at the agency level, none for the public, only the report.	Interactive portal on ArcGIS map viewer for the public, and more explicit maps for agency partners.	All spatial data will be transferred to Nevada Department of Wildlife to be displayed on their Wildlife Connectivity online mapping tool.
Number of areas identified as priority	Top 11 wildlife corridors as the priority, and also about 50 additional areas that did not score as high. 60 WVC hot spots; 10 wildlife corridors.	12 Connected Landscapes of Statewide Significance. For transportation there were 96 ecological priority zones, and 60 wildlife-related safety priority zones, with a list of 38 top locations with the greatest potential for mitigation.	Top 30 segments identified as priorities. Supporting information provided guidance on species-specific WVC and connectivity priorities at a statewide scale.
Public input, meetings	6 initial public meetings at the start, 4 took place then Covid-19 pandemic shut down these interactions; took public comment through development, and 2 public webinars to receive input after draft was out. Tribal meetings, and one-on-one Tribal meetings, input from about one dozen of 26 Tribes. Received public input continuously.	Dozens of meetings with Technical Advisory Team of outside reviewers and advisors, about 7 meetings with Implementation Advisory Team, multiple one-on-one meetings with Tribes and Tribal webinars, 3 public webinars throughout the process. Received public input continuously and through a final 3-week period.	Process began with an "Inventory of Wildlife Connectivity Needs" which was informed by over 60-individual responses from 20 entities representing federal, state, local, and tribal land and resource managers. Identification and weighting of criteria initiated during a one-day stakeholder workshop with land and resource management agencies. Nevada Department of Wildlife was a key partner in the process from start to finish.
Cost	\$500,000.	Greater than \$500,000 because it included agency personnel time as well as the three scientific consulting companies and non-profit costs.	Approximately \$500,000.
Time Frame	30 months	18 months	24 months
Team members' organizations	New Mexico DOT, New Mexico Game and Fish, DBS&A consulting firm, Wildlife Connectivity Institute, Arizona Game and Fish, National Wildlife Foundation, U.S. Forest Service, Bohannon Huston, Inc (Engineering), and T. Brennan (Engineering).	Washington Department of Fish and Wildlife, Washington Department of Transportation, Conservation Northwest, TerrAdapt, Wildlife Connectivity Institute, Conservation Biology Institute.	Nevada DOT, Nevada Department of Wildlife, HDR Engineering, Inc., BEC Environmental, Inc., ECO-resolutions, LLC., Pathways for Wildlife.

Including Wildlife Considerations into the Transportation Planning Process

Wildlife are increasingly being considered by transportation agencies and their partners in transportation planning, thanks in part to efforts to identify the priority areas of concern for wildlife-vehicle conflict (**Figure 15**). The collection and analysis of data, expert opinion, habitat maps, transportation plans, landownership, models, and other information are used by researchers and agencies to direct planning efforts for mitigating transportation for wildlife movement and the reduction of wildlife-vehicle collisions. This study will help Missouri direct such efforts to the most dangerous WVCs hot spots and ecologically important areas. The maps and data gathered and generated in this study can be input at all phases of transportation, from long-range transportation plans to daily maintenance and operations.

Figure 15: The transportation planning process: data needed, transportation agency divisions, and outside partners important to the creation of wildlife mitigation (Cramer et al. 2022a).



References

- ARC (Animal Road Crossing) Solutions. 2017. *Highway crossing structures for wildlife: Benefits of a national commitment to increase driver and animal safety*. ARC Species Publication No. 1. Prepared by ARC Solutions. <https://arc-solutions.org/wp-content/uploads/2017/04/ARC-Special-Pub-White-Paper.pdf>.
- AzDOT (Arizona Department of Transportation). n.d. "Wildlife Escape Measures." Wildlife Connectivity. Accessed February 21, 2025. <https://azdot.gov/sites/default/files/2019/06/wildlife-escape-measures.pdf>.
- Ballestero, Tom, Dave Burdick, Lauren White, Sandra Houghton, and Josh Megysey. 2023. *Design Guidance for Wetland-Road Crossings to Reduce Blanding's Turtle Mortality Risk*. November 10, 2023. Prepared by University of New Hampshire, New Hampshire Fish and Game, and New Hampshire Department of Environmental Services. <https://www.wildlife.nh.gov/sites/g/files/ehbemt746/files/inline-documents/sonh/10nov2023-guidance-for-wetland-road-crossings-for-blandings-turtles.pdf>.
- Baxter-Gilbert, James H., Julia L. Riley, David Lesbarreres, and Jacqueline D. Litzgus. 2015. "Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness." *PLoS ONE* 10 (3): e0120537. doi:10.1371/journal.pone.0120537.
- Benten, Anke, Torsten Hothorn, Torsten Vor, and Christian Ammer. 2018a. "Wildlife warning reflectors do not mitigate wildlife-vehicle collisions on roads." *Accident Analysis & Prevention* 120:64-73. <https://doi.org/10.1016/j.aap.2018.08.003>.
- Benten, Anke, Peter Annighofer, and Torsten Vor. 2018b. "Wildlife Warning Reflectors' Potential to Mitigate Wildlife-Vehicle Collisions – A Review on the Evaluation Methods." *Frontiers in Ecology and Evolution* 6:37. <https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2018.00037/full>.
- Bil, Michal, Richard Andrasik, Tomas Bartonicka, Zuzana Krivankova, and Jiri Sedonik. 2017. "An evaluation of odor repellent effectiveness in prevention of wildlife-vehicle collisions." *Journal of Environmental Management* 205:209-214. <https://doi.org/10.1016/j.jenvman.2017.09.081>.
- Bil, Michal, Clara Grilo, Jan Kubecek, Jiri Sedonik, Richard Andrasik, Vojtech Cicha, Filippo Favilli, Julia Stauder, Fabian Schwingshacki, Ioannis Vogiatzakis, Vassilis Litskas, Tea Arvaj, Koulla Michael, Maria Elia, Savas Zotos, and Lefkios Sergides. 2019. *Wildlife Vehicle Collisions: Road ecology, monitoring and mitigation, citizen science, pedagogical and socioeconomic aspects*. May 2019. Prepared for the ERASMUS+ "EnVerOS" Intellectual Output 1. <http://www.enveros.eu/>.
- Bil, Michal, Tomas Kusta, Richard Andrasik, Vojtech Cicha, Hana Brodska, Milos Jezek, and Zdenek Keken. 2020. "No clear effect of odour repellents on roe deer behaviour in the vicinity of roads." *Wildlife Biology* 4:1-11. <https://doi.org/10.2981/wlb.00744>.

- Bil, Michal, Jiri Sedonik, Richard Andrasik, Tomas Kusta, and Zdenek Keken. 2024. "Olfactory repellents decrease the number of ungulate-vehicle collisions on roads: Results of a two-year carcass study." *Journal of Environmental Management*. 365:121561. <https://doi.org/10.1016/j.jenvman.2024.121561>.
- Bond, Amy R. and Darryl N. Jones. 2023. "Wildlife Warning Signs: Public Assessment of Components, Placement and Designs to Optimise Drive Response." *Animals* 3(4): 1142-1161. <https://doi.org/10.3390/ani3041142>.
- Brennan, Liam, Emily Chow, and Clayton Lamb. 2022. "Wildlife overpass structure size, distribution, effectiveness, and adherence to expert design recommendations." *PeerJ* 10:e14371. <https://doi.org/10.7717/peerj.14371>.
- Brieger, Falko, Robert Hagen, Daniela Vetter, Carsten F. Dormann, and Ilse Storch. 2016. "Effectiveness of light-reflecting devices: A systematic reanalysis of animal-vehicle collision data." *Accident Analysis & Prevention* 97:242-260. <https://doi.org/10.1016/j.aap.2016.08.030>.
- Clevenger, Anthony P. and Marcel P. Huijser. 2011. *Wildlife Crossing Structure Handbook Design and Evaluation in North America*. FHWA-CFL/TD-11-003. March 2011. Prepared for Federal Land Highway Division. https://www.fhwa.dot.gov/clas/ctip/wildlife_crossing_structures/default.aspx#toc.
- Cramer, Patricia. 2012. *Determining Wildlife Use of Wildlife Crossing Structures Under Different Scenarios*. UT-12.07. May 2012. Prepared for Utah Department of Transportation Research Division. <https://rosap.nrl.bts.gov/view/dot/24501>.
- Cramer, Patricia. 2014. "Culvert, Bridge, and Fencing Recommendations for Big Game Wildlife Crossings in Western United States Based on Utah Data." *TRB 2014 Annual Meeting*, Washington, D.C. <https://fr.ail.ca/wp-content/uploads/2017/07/Utah-Wildlife-Paper.pdf>.
- Cramer, Patricia and Joseph Flower. 2017. *Testing New Technology to Restrict Wildlife Access to Highways: Phase I*. UT-17.15. August 2017. Prepared for Utah Department of Transportation Research Division and Region Four. https://rosap.nrl.bts.gov/view/dot/32771/dot_32771_DS1.pdf.
- Cramer, Patricia and Robert Hamlin. 2017. *Evaluation of Wildlife Crossing Structures on US 93 in Montana's Bitterroot Valley*. FHWA/MT-17-003/8194. January 2017. Prepared for Montana Department of Transportation. <https://doi.org/10.21949/1518235>.
- Cramer, Patricia and Robert Hamlin. 2019. *U.S. Highway 89 Kanab-Paunsaugunt Wildlife Crossing and Existing Structures Research*. UT-19.19. Prepared for Utah Department of Transportation. https://rosap.nrl.bts.gov/view/dot/63544/dot_63544_DS1.pdf.
- Cramer, Patricia and Robert Hamlin. 2020. *US 189 Wildlife Crossing Structures and Escape Ramps Monitoring Final Report*. UT-1X.XX. March 2020. Prepared for Utah Department of Transportation.

https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/6307deb2247ead644d4600f5/1661460157748/UT+US+189+Wildlife+Crossing+Structures+and+Escape+Ramps+Monitoring_FINAL+REPORT+3-3-2020.pdf.

Cramer, Patricia and Robert Hamlin. 2024a. *State Highway 13 Wildlife Mitigation Measures Research Study: 2024 Fourth Quarter and Annual Report*. Study No. 120.02. Prepared for Colorado DOT. <https://www.wildlifeconnectivity.org/colorado-sh13-reports-1>.

Cramer, Patricia. and Robert Hamlin. 2024b. *US 160/SH151 Wildlife Mitigation Research Project Study Number R122.01, 2024 Annual Report to Colorado Department of Transportation*. <https://www.wildlifeconnectivity.org/colorado-chimney-reports>.

Cramer, Patricia and Robert Hamlin. 2025. *Utah SR 73 Eagle Mountain Mule Deer Crosswalk and Wildlife-Detection Driver Warning System Research 2024 Annual Report*. Prepared for Utah DOT. <https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/681e6ec14a3f9144527601c3/1746824911896/Eagle+Mtn+2024+Annual+Report+May+9+2025+FINAL.pdf>.

Cramer, Patricia, Monte Aldridge, Randall Taylor, and Bill Ostrum. 2014. "Collaborative Research Effort Identifies Effective Wildlife Crossing Practices in Utah." *Federal Highway Administration: Success in Stewardship*, January 2014. https://www.environment.fhwa.dot.gov/pubs_resources_tools/publications/newsletters/jan14nl.pdf.

Cramer, Patricia, Julia Kintsch, Kari Gunson, Fraser Shilling, Mary Kenner, and Cheryl Chapman. 2016. *Reducing WVC in South Dakota*. SD2014-03-F. July 29. Prepared for the South Dakota Department of Transportation. <https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/6335019e4772c23bf39be169/1664418229065/SOUTH+DAKOTA+WVC+Reduction+Study+2016+Cramer+et+al.+Full+Report+FINAL.pdf>.

Cramer, Patricia, Jean-Luc E. Cartron, Kenneth C. Calhoun, Jeffery W. Gagnon, Matthew B. Haverland, Mark L. Watson, Samuel A. Cushman, Ho Yi Wan, Julie A. Kutz, Jeremy N. Romero, Terence J. Brennan, Jeanette A. Walther, Chad D. Loberger, Haley P. Nelson, Trent D. Botkin, and James G. Hirsch. 2022. *New Mexico Wildlife Corridors Action Plan*. June 2022. Prepared for New Mexico Department of Transportation and New Mexico Department of Fish & Game. https://wildlifeactionplan.nmdotprojects.org/wp-content/uploads/sites/39/2022/07/Wildlife-Corridors-Action-Plan_June-2022_FINAL-reduced.pdf.

D'Angelo, Gino and Rodney van der Ree. 2015. *Handbook of Road Ecology: Use of Reflectors and Auditory Deterrents to Prevent Wildlife-Vehicle Collisions*. John Wiley & Sons Ltd. <https://onlinelibrary.wiley.com/doi/book/10.1002/9781118568170>.

Dodd, Norris L., Jeffrey W. Gagnon, Scott C. Sprague, Susan Boe, and Raymond E. Schweinsburg. 2012. *Wildlife Accident Reduction Study and Monitoring: Arizona State*

- Route 64. FHWA-AZ-12-626. November 2012. Prepared for Arizona Department of Transportation. https://rosap.ntl.bts.gov/view/dot/25279/dot_25279_DS1.pdf.
- Donaldson, Bridget M. 2017. *Improving Animal-Vehicle Collision Data for the Strategic Application of Mitigation*. FHWA/VTRC 18-R16. December 2017. Prepared for Virginia DOT. <https://vtrc.virginia.gov/media/vtrc/vtrc-pdf/vtrc-pdf/18-R16.pdf>.
- Donaldson, Bridget M. and Young-Jun Kweon. 2019. "Effectiveness of Seasonal Deer Advisories on Changeable Message Signs as a Deer Crash Mitigation Tool." *Transportation Research Record* 2673 (12): 548-557. <https://doi.org/10.1177/0361198118823204>.
- Elmeros, Morten, Jens K. Winbladh, Poul N. Andersen, Aksel Bo Madsen, and Jens T. Christensen. 2011. "Effectiveness of odour repellents on red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*): a field test." *European Journal of Wildlife Research* 57:1332-1226. DOI 10.1007/s10344-011-0517-y.
- Found, Rob and Mark S. Boyce. 2011. "Warning Signs Mitigate Deer-Vehicle Collisions in an Urban Area." *Wildlife Society Bulletin* 35 (3):291-295. DOI:10.1002/wsb.12.
- Gagnon, Jeffrey W., Norris L. Dodd, Scott Sprague, Chad Loberger, Rob Nelson, Susan Boe, and Raymond E. Schweinsburg. 2014. *Evaluation of Measures to Promote Desert Bighorn Sheep Highway Permeability: U.S. Route 93*. FHWA-AZ-14-677. January 2014. Prepared for Arizona Department of Transportation. https://rosap.ntl.bts.gov/view/dot/26912/dot_26912_DS1.pdf.
- Gagnon, Jeffery W., Chad D. Loberger, Scott C. Sprague, Kari S. Ogren, Susan L. Boe, and Raymond E. Schweinsburg. 2015. "Cost-effective approach to reducing collisions with elk by fencing between existing highway structures." *Human-Wildlife Interactions* 9 (2):248-264. <https://doi.org/10.26077/z5kk-s204>.
- Gagnon, Jeffrey W., Chad D. Loberger, Scott C. Sprague, Susan R. Boe, Kari S. Ogren, and Raymond E. Schweinsburg. 2017. *Wildlife-Vehicle Collision Mitigation on State Route 260: Mogollon Rim to Show Low*. FHWA-AZ-17-706. August 2017. Prepared for Arizona Department of Transportation. https://apps.azdot.gov/ADOTLibrary/publications/project_reports/pdf/SPR706.pdf.
- Gagnon, Jeffrey W., Norris L. Dodd, Scott C. Sprague, Chad D. Loberger, and Raymond E. Schweinsburg. 2018. "Animal-activated highway crosswalk: long-term impact on elk-vehicle collisions, vehicle speeds, and motorist braking response." *Human Dimensions of Wildlife* 24 (2): 132-147. <https://doi.org/10.1080/10871209.2019.1551586>.
- Gagnon, Jeffery W., Colin A. Beach, Timothy P. McCarthy, Chad D. Loberger, Haley P. Nelson, and Scott C. Sprague. 2023. *Evaluation of Right-of Way Fence Tags to Reduce Animal-Vehicle Collisions*. SPR 000-1(023) 758. May 2023. Prepared for the Arizona Department of Transportation. https://rosap.ntl.bts.gov/view/dot/67383/dot_67383_DS1.pdf.

- Gamo, Dr. R. Scott, Tom Hart, Dr. Joshua J. Millspaugh. 2023. *Deterring Wildlife Use of Road Right-of-Ways in Wyoming*. WYDOT Project Champions. January 5. Prepared for Wyoming Department of Transportation.
https://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Planning/Research/Deterring_Wildlife_Use.pdf.
- Gordon, Kelly M, Mark C. McKinstry, and Stanley H. Anderson. 2004. "Motorist response to a deer-sensing warning system." *Wildlife Society Bulletin* 32(2): 565-573.
[https://doi.org/10.2193/0091-7648\(2004\)32\[565:MRTADW\]2.0.CO;2](https://doi.org/10.2193/0091-7648(2004)32[565:MRTADW]2.0.CO;2).
- Gray, Mary. 2009. *Advances in Wildlife Crossing Technologies*. FHWA-HRT-09-006. September/October 2009. <https://highways.dot.gov/public-roads/septoct-2009/advances-wildlife-crossing-technologies>.
- Grosman, Paul D., Jochen A.G. Jaeger, Pascale M. Biron, Christian Dussault, and Jean-Pierre Ouellet. 2011. "Trade-off between road avoidance and attraction by roadside salt pools in moose: An agent-based model to assess measures for reducing moose-vehicle collisions." *Ecological Modelling* 222 (8):1423-1435.
<https://doi.org/10.1016/j.ecolmodel.2011.01.022>.
- Grubb, Teryl G., Roy G. Lopez, and Martha M. Ellis. "Winter scavenging of ungulate carrion by bald eagles, common ravens, and coyotes in northern Arizona." *Journal of Raptor Research* 52(4): 471-483. <https://doi.org/10.3356/JRR-17-93.1>.
- Gunson, Kari, David Seburn, Julia Kintsch, and Joe Crowley. 2016. *Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario*. April 2016. Prepared for Ontario Ministry of Natural Resources and Forestry.
https://files.ontario.ca/bmp_herp_2016_final_final_resized.pdf.
- Harman, Kristine E., Kadie Omlor, and Viorel Popescu. 2023. "Evaluating fence-end treatments for migratory amphibians." *Frontiers in Ecology and Evolution*. 11:1008462.
<https://doi.org/10.3389/fevo.2023.1008462>.
- Hammer, Mary L. 2001. "Effectiveness of Earthen Escape Ramps in Reducing Big Game Mortality in Utah." Master's Thesis. Utah State University.
<https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=7494&context=etd>.
- Heaven, Paul C., Jacqueline D. Litzgus, M. Tim Tinker. 2019. "A Unique Barrier Wall and Underpass to Reduce Road Mortality of Three Freshwater Turtle Species." *Copeia* 107(1): 92-99. <https://doi.org/10.1643/CH-18-137>.
- Huijser, Marcel P. and Samantha C. Getty. 2023. *Effective Jump-outs for White-tailed Deer and Mule Deer*. FHWA/MT-23-004/9923-808. September 2023. Prepared for the Montana Department of Transportation.
https://ftp.mdt.mt.gov/other/webdata/external/research/docs/research_proj/wildlife_fences_jumpouts/Interim-Report-1.pdf.

- Huijser, M.P., A. Kociolek, P. McGowen, A. Hardy, A.P. Clevenger, and R. Ament. 2007. *Wildlife-Vehicle Collision and Crossing Mitigation Measures: A Toolbox for the Montana Department of Transportation*. FHWA/MT-07-002/8117.34. May 2007. Prepared by Western Transportation Institute. https://www.mdt.mt.gov/other/webdata/external/research/docs/research_proj/wildlife_crossing_mitigation/final_report.pdf.
- Huijser, Marcel P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith, and R. Ament. 2008. *Wildlife-Vehicle Collision Reduction Study: Report to Congress*. FHWA-HRT-08-034. August 2008. Prepared for the Federal Highway Administration. <https://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf>.
- Huijser, Marcel P., Tiffany D. Holland, Matt Blank, Mark C. Greenwood, Pat T. McGowen, Barrett Hubbard, and Shaowei Wang. 2009. *The Comparison of Animal Detection Systems in a Test-Bed: A Quantitative Comparison of System Reliability and Experiences with Operation and Maintenance*. FHWA/MT-09-5048. April 23. Prepared for the Federal Highway Administration and the Montana Department of Transportation. <https://doi.org/10.21949/1518286>.
- Huijser, Marcel P., Angela V. Kociolek, Tiffany D.H. Allen, Patrick McGowen, Patricia C. Cramer, and Marie Venner. 2015. *Construction Guidelines for Wildlife Fencing and Associated Escape and Lateral Access Control Measures*. April 2015. Prepared for the American Association of State Highway and Transportation Officials. [https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25\(84\)_FR.pdf](https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(84)_FR.pdf).
- Huijser, Marcel P., Elizabeth R. Fairbank, Whisper Camel-Means, Jonathan Graham, Vicki Watson, Pat Basting, and Dale Becker. 2016. "Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife-vehicle collisions and providing safe crossing opportunities for large mammals." *Biological Conservation* 197: 61-68. <https://doi.org/10.1016/j.biocon.2016.02.002>.
- Huijser, M.P., R.J. Ament, M. Bell, A.P. Clevenger, E.R. Fairbank, K.E. Gunson, and T. McGuire. 2021. *Animal Vehicle Collision Reduction and Habitat Connectivity Pooled Fund Study – Literature Review*. 701-18-803 TO 1 – Literature Review. December 2021. Prepared for Nevada Department of Transportation. <https://largelandscapes.org/wp-content/uploads/2022/01/Animal-vehicle-collision-reduction-and-habitat-connectivity-study-cost-effective-solutions-literature-review.pdf>.
- Jacobson, Sarah L. 2005. *Mitigation Measures for Highway-caused Impacts to Birds*. USDA Forest Service General Technical Report PSW-GTR-191. Prepared by USDA Forest Service, Redwood Sciences Laboratory, Pacific Southwest Research Station. https://www.fs.usda.gov/psw/publications/documents/psw_gtr191/psw_gtr191_1043-1050_jacobson.pdf.

- Jaeger, Jochen A.G. and Lenore Fahrig. 2004. "Effects of Road Fencing on Population Persistence." *Conservation Biology* 18 (6): 1651-1657. <https://doi.org/10.1111/j.1523-1739.2004.00304.x>.
- Jones, Nathan F., Nova Simpson, Julia Kintsch, Mark Traxler, Juan Garcia, Tanya Diamond, and Danny Rakestraw. 2025. *Nevada Statewide Wildlife Crossings Prioritization Study*. April 2025. Prepared for Nevada DOT. <https://www.dot.nv.gov/home/showpublisheddocument/23408>.
- KCal News. 2021. "5 Drainage Culverts Retrofitted For Safer Wildlife Crossing Along 12-Mile Stretch Of State Route 118 In Ventura County." *KCal News*, April 14. <https://www.cbsnews.com/losangeles/news/5-drainage-culverts-retrofitted-safer-wildlife-crossing-12-mile-stretch-state-route-118-ventura-county/>.
- Keken, Zdenek, Lenka Wimmerova, Olga Solcova, Tomas Kusta, and Petra Dvorakova. 2024. "Olfactory Repellents in Road Ecology: What We Know and What to Focus on in the Future." *Sustainability* 16 (14):5920. <https://doi.org/10.3390/su16145920>.
- Kintsch, Julia and Dr. Patricia C. Cramer. 2011. *Permeability of Existing Structures for Terrestrial Wildlife: A Passage Assessment System*. WA-RD 777.1. July 2011. Prepared for Washington State Department of Transportation. <https://www.wsdot.wa.gov/research/reports/fullreports/777.1.pdf>.
- Kintsch, Julia, Patricia Cramer, Paige Singer, and Michelle Cowardin. 2021. *State Highway 9 Wildlife Mitigation Monitoring*. March 2021. Prepared for Colorado Department of Transportation. <https://static1.squarespace.com/static/60baf2ed8791194056e335f8/t/672257b7d4e8d11beadc03bd/1730303946543/SH+9+Wildlife+Crossings+Monitoring+CDOT+2021-01.pdf>.
- Kozarek, Jessica and Matt Hernick. 2024. *Thinking inside the box (culvert): Developing a low-cost, easy-to-install retrofit prototype for fish passage*. CTS 23-11. May 2024. Prepared for Center for Transportation Studies. <https://cts-d8resmod-prd.oit.umn.edu/pdf/cts-23-11.pdf>.
- Laurance, William F. 2015. "Wildlife Struggle in an Increasingly Noisy World." *PNAS* 112(39): 11995-11996. <https://doi.org/10.1073/pnas.1516050112>.
- Leete, Peter. 2014. *Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001*. Version 4. Prepared for MnDNR. https://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html.
- Lehnert, Mark E. and John A. Bissonette. 1997. "effectiveness of highway crosswalk structures at reducing deer-vehicle collisions." *Wildlife Society Bulletin* 25(4): 809-818. <https://www.jstor.org/stable/3783727>.

- Loberger, Chad D, Jeff W. Gagnon, Haley P. Nelson, Colin A. Beach, and Scott C. Sprague. 2021. *Determining Effectiveness of Wildlife-Vehicle Collision Mitigation Projects: Phase One*. R917034. February 28. Prepared for New Mexico DOT Research Bureau. https://wildlifeactionplan.nmdotprojects.org/wp-content/uploads/sites/39/2021/09/NM17ENV-01_PhaseOne_FinalReport_20210308.pdf.
- Markle, Tricia and Seth Stapleton. 2022. *Reduce vehicle-animal collisions with installation of small animal exclusion fencing*. MN 2022-19. June 2022. Prepared for Minnesota Department of Transportation. <https://mdl.mndot.gov/items/202219>.
- MDC. 2024. "Field Guide." Discover Nature. Accessed December 2, 2024. <https://mdc.mo.gov/discover-nature/field-guide>.
- MN DNR (Minnesota Department of Natural Resources). 2008. "Blanding's Turtle (*Emydoidea blandingii*).". Environmental Review Fact Sheet Series: Endangered, Threatened, and Special Concern Species of Minnesota. Updated March 2008. https://files.dnr.state.mn.us/natural_resources/animals/reptiles_amphibians/turtles/blandings_turtle/factsheet.pdf.
- New Jersey Division of Fish and Wildlife. 2019. *Connecting Habitat Across New Jersey (CHANJ): Guidance Document, Version 1.0*. Prepared by New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program. https://dep.nj.gov/njfw/wp-content/uploads/njfw/chanj_guidance.pdf.
- Nichols, A.P., M.P. Huijser, R. Ament, S. Dayan, and A. Unnikrishnan. 2014. *Evaluation of deer-vehicle collision rates in West Virginia and a review of available mitigation techniques*. RP-291. August 25. Prepared for West Virginia Department of Transportation Division of Highways. https://rosap.ntl.bts.gov/view/dot/28037/dot_28037_DS1.pdf.
- Nielson, Lindsey Peterson. 2020. "'Guzzler' installed in Spanish Fork Canyon to provide wildlife easy access to water." *ABC4.com*, December 10. <https://www.abc4.com/news/local-news/guzzler-installed-in-spanish-fork-canyon-to-provide-wildlife-easy-access-to-water/>.
- Normandeau Associates, Inc. 2012. *Deer-Vehicle Crash, Ecological, and Economic Impacts of Reduced Roadside Mowing – Final Report*. May 2012. Prepared for The Federal Highway Administration. R-19977.003. <https://www.intrans.iastate.edu/wp-content/uploads/sites/10/2018/11/DVC-Mowing.pdf>.
- Ontario Ministry of Transportation. 2017. "Environmental guide for mitigating road impacts to wildlife." March 2017. Prepared by Eco-Kare International. <https://eco-kare.com/>.
- Paige, Christine. 2008. *A Landowner's Guide to Wildlife Friendly Fences: How to Build Fence with Wildlife in Mind*. Private Land Technical Assistance Program, Montana Fish, Wildlife and Parks, Helena, Montana. <https://www.nrcs.usda.gov/sites/default/files/2022-09/WildlifeFriendlyFences.pdf>.

- Paige, Christine. 2016. *A Landowners Guide to Wildlife Friendly Fences: How to Build Fences with Wildlife in Mind*. Saskatchewan Ministry of the Environment. <https://www.nrcs.usda.gov/sites/default/files/2022-09/WildlifeFriendlyFences.pdf>.
- Paige, Christine. 2025. *A Wyoming Landowner's Handbook to Fences and Wildlife: Practical Tips for Fencing with Wildlife in Mind*. Third edition. Wyoming Game and Fish Department, Cheyenne, Wyoming. https://wgfd.wyo.gov/sites/default/files/2025-04/Wyoming%20Fences%20&%20Wildlife%20Handbook-031725.pdf?utm_source=PRESSRELEASE&utm_medium=DIGITAL&utm_campaign=HABITAT&utm_content=2025FENCINGBOOKLET.
- Pojar, Thomas M., Richard A. Prosenice, Dale F. Reed, and Thomas N. Woodard. 1975. "Effectiveness of a Lighted, Animated Deer Crossing Sign." *The Journal of Wildlife Management* 39 (1):87-91. <https://doi.org/10.2307/3800469>.
- Putman, R.J. and J. Langbein. 2024. *Deer Vehicle Collisions – a review of mitigation measures and their effectiveness*. NatureScot Research Report 1354. Prepared for NatureScot. Accessed February 27, 2025. <https://www.nature.scot/doc/naturescot-research-report-1354-deer-vehicle-collisions-review-mitigation-measures-and-their#improvements+to+road+lighting-01>.
- Rea, Roy V. 2003. "Modifying roadside vegetation management practices to reduce vehicular collisions with moose *Alces alces*." *Wildlife Biology* 9 (2):81-91. <https://doi.org/10.2981/wlb.2003.030>.
- Riginos, Corinna, Morgan W. Graham, Melanie J. Davis, Andrew B. Johnson, Alexander B. May, Kevin J. Ryer, and L. Embere Hall. 2018. "Wildlife Warning Reflectors and White Canvas Reduce Deer-Vehicle Collisions and Risky Road-Crossing Behavior." *Wildlife Society Bulletin* 42(1): 119-130. <https://doi.org/10.1002/wsb.862>.
- Scheifele, Peter M., David G. Browning, and Lesa M. Collins-Scheifele. 2003. "Analysis and effectiveness of deer whistles for motor vehicles: frequencies, levels, and animal threshold responses." *Acoustic Research Letters Online* 4 (3). DOI: <http://dx.doi.org/10.1121/1.1582071>.
- Seidler, Renee G., David S. Green, and Jon P. Bechmann. 2018. "Highways, crossing structures and risk: Behaviors of Greater Yellowstone pronghorn elucidate efficacy of road mitigation." *Global Ecology and Conservation*. 15:e00146. <https://doi.org/10.1016/j.gecco.2018.e00416>.
- Shilling, Fraser, Amy Collins, Annabelle Louderback-Valenzuela, Parisa Farman, Mia Guarnieri, Travis Longcore, Benjamin Banet, and Harrison Knapp. 2018. *Wildlife-Crossing Mitigation Effectiveness with Traffic Noise and Light*. June 2018. Prepared by the National Center for Sustainable Transportation. <https://www.researchgate.net/deref/https%3A%2F%2Fescholarship.org%2Fuc%2Fitem%2F8893d8zw?tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxxpY2F0aW9uIiwicGFnZSI6InB1YmxxpY2F0aW9uIn19>.

- Smith, Daniel J, Julia Kintsch, Patricia Cramer, Sandra L. Jacobson, and Stephen Tonjes. 2015. *Modifying structures on existing roads to enhance wildlife passage*. Chapter 10 (pp. 208-228) in Andrews KM, Nanjappa P, and Riley SPD, eds. *Roads and ecological infrastructure; Concepts and applications for small animals*. John Hopkins University Press.
- Soanes, Kylie, Jochen A.G. Jaeger, Lenore Fahrig, Scott Findlay, Jeff Houlahan, Rodney van der Ree, Edgar A. van der Grift. 2016. "How Effective Is Road Mitigation at Reducing Road-Kill? A Meta-Analysis." *PLOS One* 11(11): e0166941. <https://doi.org/10.1371/journal.pone.0166941>.
- Sullivan, Todd L., Allan F. Williams, Terry A. Messmer, Laurie A. Hellinga, and Sergey Y. Kyrychenko. 2004. "Effectiveness of Temporary Warning Signs in Reducing Deer-Vehicle Collisions during Mule Deer Migration." *Wildlife Society Bulletin* 32 (3):907-915. <https://www.jstor.org/stable/3784815>.
- USDA NRCS (United States Department of Agriculture Natural Resources Conservation Service). 2013. "Guidelines for Use of Snake-Friendly Erosion Control Blankets." Biology Fact Sheet. October 2013. https://efotg.sc.egov.usda.gov/references/public/IN/Fact_Sheet_Biology_Snake-Friendly_Netting.pdf
- USFWS. n.d. "Make the Change to Wildlife-Friendly Erosion Control Products!" Protecting Wildlife. Accessed February 20, 2025. <https://www.fws.gov/initiative/protecting-wildlife/make-change-wildlife-friendly-erosion-control-products#:~:text=To%20minimize%20wildlife%20entanglement%20and,%2C%20sisal%2C%20or%20coir%20fiber>.
- U.S. Forest Service. 2017. "Retrofitting Existing Structures for Wildlife Passage: Assessment Tools." Wildlife Crossings Toolkit. Updated April 7. <https://www.fs.usda.gov/wildlifecrossings/resources/retrofitting-structures.php>.
- Valitski, Sharon A., Gion J. D'Angelo, George R. Gallagher, David A. Osborn, Karl V. Miller, and Robert J. Warren. 2009. "Deer Responses to Sounds from a Vehicle-Mounted Sound-Production System." *Journal of Wildlife Management* 73 (7):1072-1076. <http://www.jstor.org/stable/20616763>.
- Waring, G.H., J.L. Griffis, and M.E. Vaughn. 1991. "White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality." *Applied Animal Behaviour Science* 29 (1-4):215-223. [https://doi.org/10.1016/0168-1591\(91\)90249-W](https://doi.org/10.1016/0168-1591(91)90249-W).
- Woltz, Hara W., James P. Gibbs, and Peter K. Ducey. 2008. "Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis." *Biological Conservation* 141 (11):2745-2750. <https://doi.org/10.1016/j.biocon.2008.08.010>.

Wood, Peggy and Michael L. Wolfe. 1988. "Intercept Feeding as a Means of Reducing Deer-Vehicle Collisions." *Wildlife Society Bulletin* 16 (4):376-380.
<http://www.jstor.org/stable/3782436>.

WRRC (Wildlife Roadsharing Resource Centre). 2025. "Mitigation Measures." Accessed February 20, 2025. <https://wildliferoadsharing.tirf.ca/research/mitigation-measures/#measures>.



B

ESRI ArcGIS Pro Analysis Methods

ESRI ArcGIS Pro Analysis Methods

The following instructions outline the procedures in ESRI ArcGIS Pro to create the 0.5-mile segment polygons around MoDOT-operated roadways and run the Optimized Hot Spot Analysis tool for the crash data and prioritization criteria.

Aggregation Polygon Methodology

Step 1. Query the *Missouri_Roads* layer to only features with these road designations:

Where: DESG *includes the value(s)*: AL, BU, CO, IS, LP, MO, OR, RA, RP, RT, SP, US, WS

Step 2. Export the filtered roads layer and call it *MoDOT_Operated_Roads*.

- Export in the appropriate coordinate system when running all geoprocessing tools in the environment settings. *NAD 1983 StatePlane Missouri Central FIPS 2402 (US Feet)* was the coordinate system used for this study

Step 3. Buffer the Roads layer by 660 feet on both sides. This is the determined study area.

- Input: *MoDOT_Operated_Roads (Polyline)*
- Output: *MoDOT_Operated_Roads_Buffer (polygon)*
- Distance Field: *660, Linear Unit: US Survey Feet*
- All other drop-downs keep default

Step 4. Dissolve *MoDOT_Operated_Roads_Buffer* Layer by the NAME field. The dissolve will combine overlapping segments with the same travelway name. I-70, for example, will just have one segment that is slightly larger than 660 feet. This will also remove duplicates on the *MoDOT_Operated_Roads*. This layer is set up so that one street /road will have an identical line placed on top of it to represent both directions of the road. One polyline/polygon per road was selected for this study.

The parameters will look like this:

- Input: *MoDOT_Operated_Roads_Buffer (polygon)*
- Output: *MoDOT_Operated_Roads_Buffer_Diss (polygon)*
- Dissolve Fields: *NAME*
- No statistics field needed
- Uncheck multipart features and unsplit lines

Step 5. Using **Xtools Pro** or **Collapse Hydro Polygon** tool generates centerlines from the dissolved polygons. This will return a centerline along roads. Note that these centerlines will not be as aligned to the original MoDOT roads layer and may not follow the basemap imagery perfectly

- Input: *MoDOT_Operated_Roads_Buffer_Diss (polygon)*

- Output: *MoDOT_Operated_Roads_CL (Polyline)*

Step 6. Use the **Generate points along Line** tool. This creates point features along the centerline layer. Points will be plotted every 0.5-miles along the line.

The parameters will look like this:

- Input: *MoDOT_Operated_Roads_CL*
- Output: *Half_Mile_Points*
- Point placement: *By Distance*
- Distance: *0.5, US Survey Miles*
- Do **not** check: include end points or accumulated distance boxes
- Distance method: *Planar*

This is where it is important to have the input features and map coordinate system in US survey feet.

Step 7. Use **Split Line at Point** tool. This tool will use the 0.5-mile separated points created in Step 6 to break or split the centerline wherever those points fall. For each split two new features are created.

The parameters will look like this:

- Input Features: *MoDOT_Operated_Roads_CL*
- Point features: *Half_Mile_Points*
- Output Features: *Half_Mile_Segments*
- Search Radius: *N/A*

Note: if the tool is taking too long to run, adding a minor search radius up to a couple of feet can speed up the process.

Step 8: Buffer the 0.5-mile segments again. This will be the final study area.

Parameter will look like this:

- Input: *Half_Mile_Segments*
- Output: *Half_Mile_Segment_Buffer*
- Distance Field: *660, Linear Unit: US Survey Feet*
- Side Type: *Full*
- End Type: *Flat*
- Method: *Planar*
- Dissolve Type: *No Dissolve*

Using Side type of Flat is important because the polygons will not overlap each other at the ends of the segment.

Step 9. Use **Simplify Shared Edges** tool. When 0.5-mile segments with sharp bends were buffered, it created overlapping, disfigured polygons. This tool helped to clean up these edges.

- Input: *Half_Mile_Segment_Buffer*
- Output: *Half_Mile_Segments_Final*
- Simplification Algorithm: *Retain critical points*
- Simplification Tolerance: *50 feet (adjust this value as necessary until the desired effect is achieved)*

Optimized Hot Spot Analysis

Step 1. Prepare the Crash data. Filter Crash data to MoDOT road Designations. AL, BU, CO, IS, LP, MO, OR, RA, RP, RT, SP, US, WS. Then filter the crash data to the most recent five years.

Step 2. Use the **Optimized Hot Spot Analysis** Geoprocessing tool.

The parameters will look like this:

- Input: *Filtered MoDOT Wildlife crashes*
- Output: *OHSa*
- Analysis Field: *Leave blank*
- Incident Data Aggregation Method: *Count Incidents within aggregation polygons*
- Polygons for Aggregating Incidents Into Counts: *Use Half_Mile_Segments_Final from Step 9*
- Override Settings: *Distance Band: 0.5, US Survey Miles*
- Export into consistent coordinate system

Prioritization Criteria Optimized Hot Spot Analysis

Step 1. Add field for each criteria below to the *OHSa* output from the crash analysis and follow the associated geoprocessing steps.

Criteria	Geoprocessing Steps
Transportation	
Wildlife-Vehicle Crash Hot Spots	Sort by the Gi_Bin_Fixed 2640_FDR field by ascending: anything with a 3 = 20, 2 = 20, 1 = 5.
Wildlife crashes per-0.5-mile segment per year	Use the Summarize Within Tool to count the number of WVCs within each segment.
Crashes with Fatality and/or Serious Injuries	Filter Crashes to Fatal or Serious crashes. Use Select by location tool with hotspot polygons and crash. Calculate field with "10" to any polygons selected.
Percentage of All Crashes that are WVC	Use Summarize Within Tool: Input the OHSa polygon, Summary features are the crashes. Summary field "WVC Count" (add a numeric field in the crash data, calculate so each record is equal to 1) the statistic will be SUM. When complete a table join with OSHA layer and summarize within output layer using the source IDS. Repeat this process with all crashes as well. Use field calculator to copy in the crash count fields. Add another field in OSHA layer, calculate WVC Count/ All Count.

Criteria	Geoprocessing Steps
Transportation Score	Total scores from the transportation criteria.
Ecological	
Traffic Volume = AADT	Filter AADT roads to only MoDOT operated designations. Add spatial join with OSHA and AADT roads. Remove all fields in field map except TOTAL AADT. Select the action to MEAN. Calculate the new field in your field.
Occupied Habitat	Select by location within a mile and calculate field.
Suitable Habitat	Select by location and calculate field.
MDC CCS Management Tiers	Start by filtering the layer with the lowest tier first. Select by location and calculate the field with the score. Repeat the process the rest of the tiers going from lowest to highest in scores .
Bridges and Culverts	Select by location and calculate field.
Ecological Score	Total scores from the ecological criteria.
Feasibility	
Land Use	Using NLCD data, query to only developed land. For each OSHA segment, determine if the segment is 25% or more covered by developed land. Utilize the summarize within geoprocessing tool. This will assign each polygon a percentage of developed land. If under 25% the polygon gets 10 points.
Protected Areas	Select by location and calculate the protected areas field. Each field selected gets 10.
Feasibility Score	Total the score from the feasibility criteria.
Final Score	Add points from all fields above

Step 2. Use the **Optimized Hot Spot Analysis** Geoprocessing tool.

The parameters will look like this:

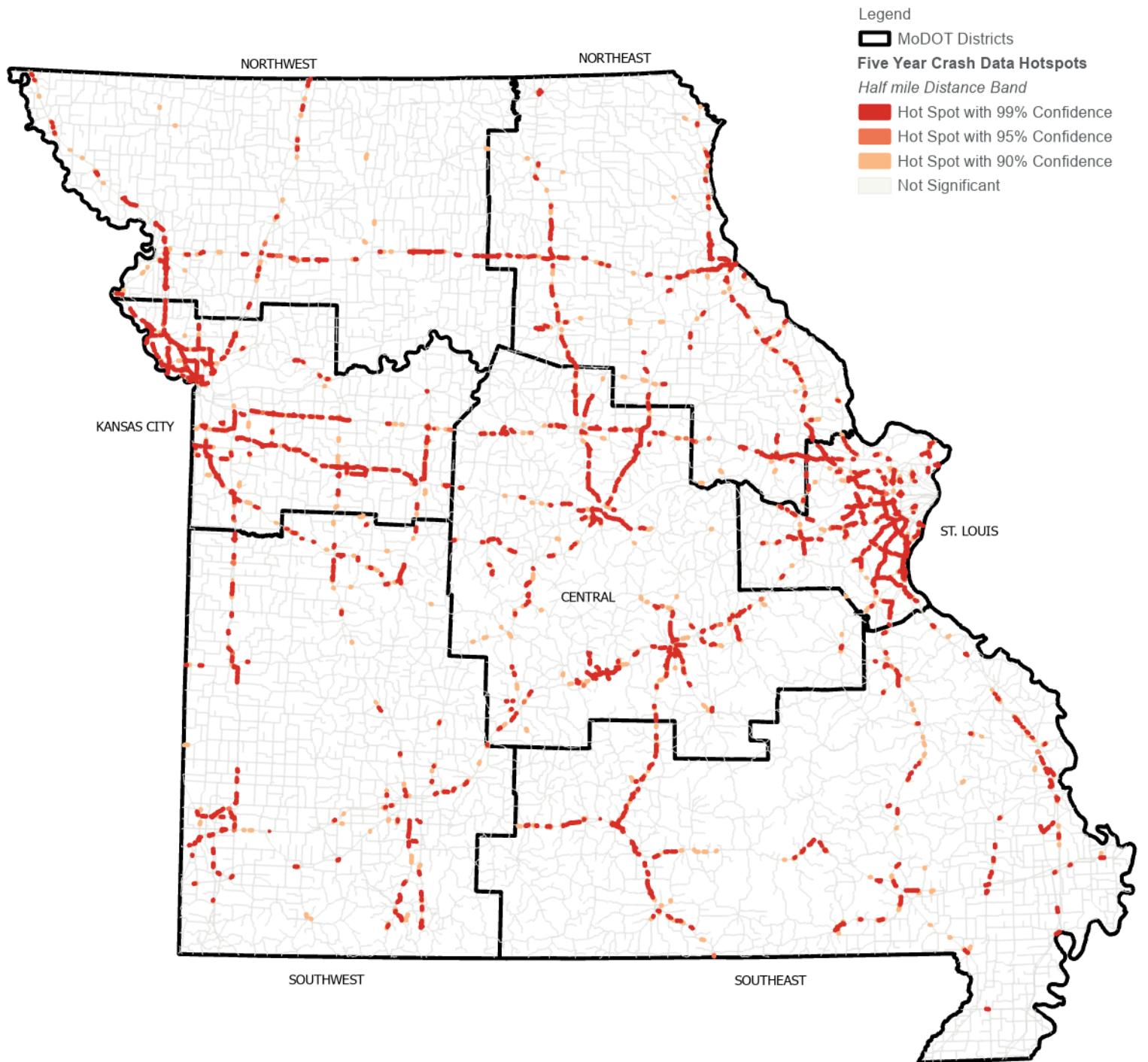
- Input: *OHSA* (includes criteria from Step 1)
- Output: *OHSA_Priority*
- Analysis Field: *Iterate for the transportation score, ecological score, and final score fields.*
- Override Settings: *Distance Band: 0.5, US Survey Miles*

Export into consistent coordinate system



C

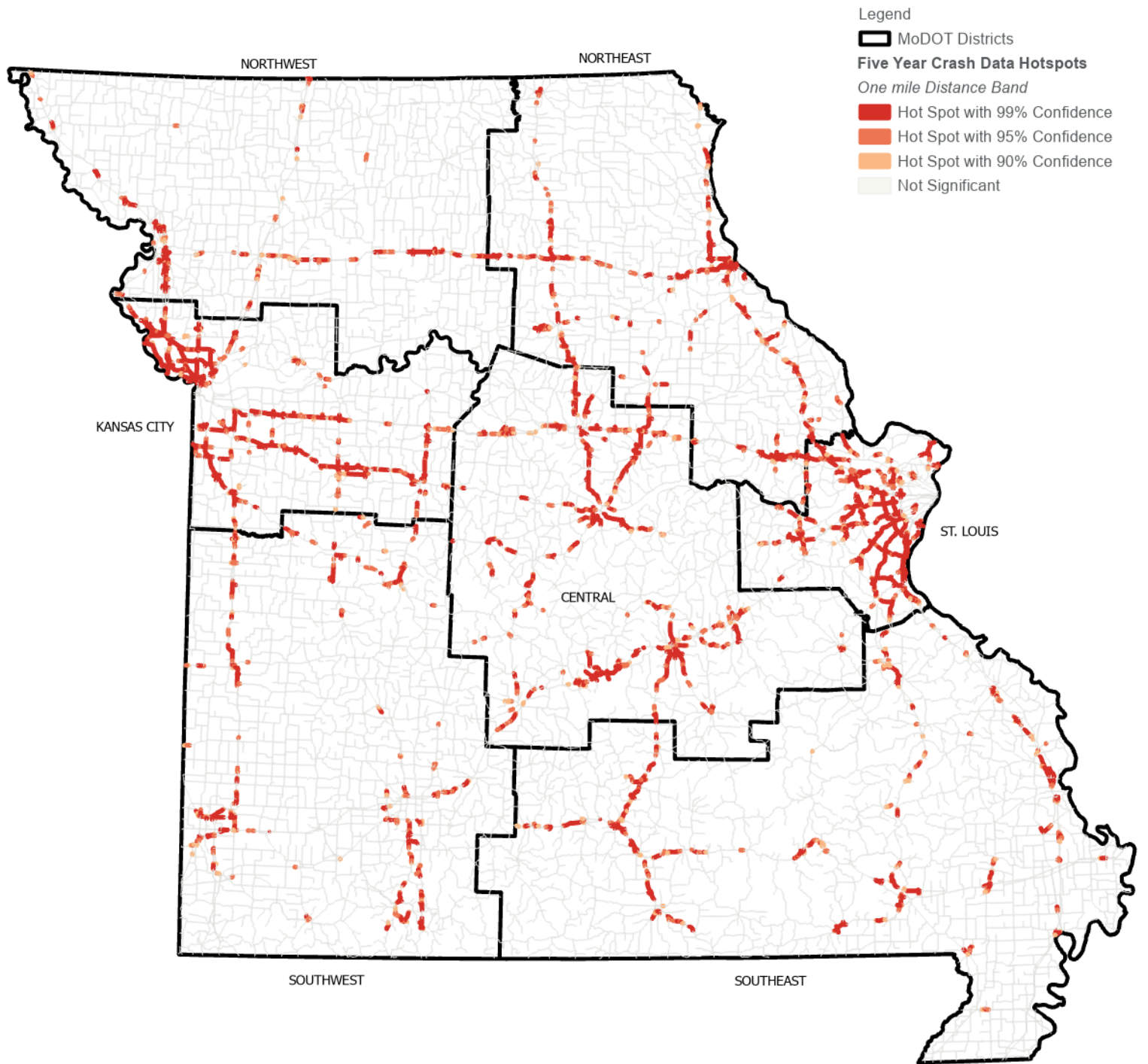
MSHP Wildlife Crash OHSA Result Figures



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



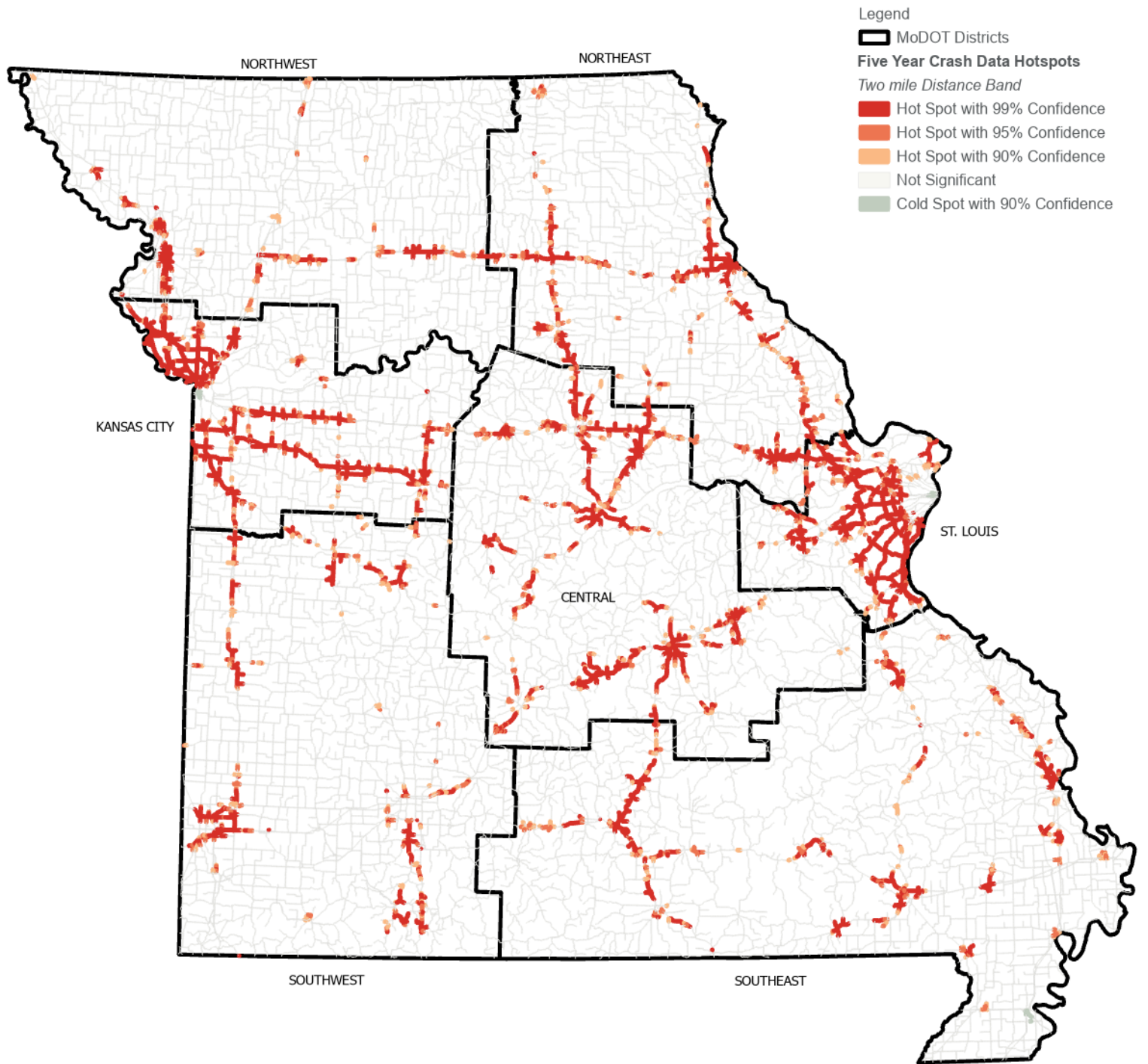
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



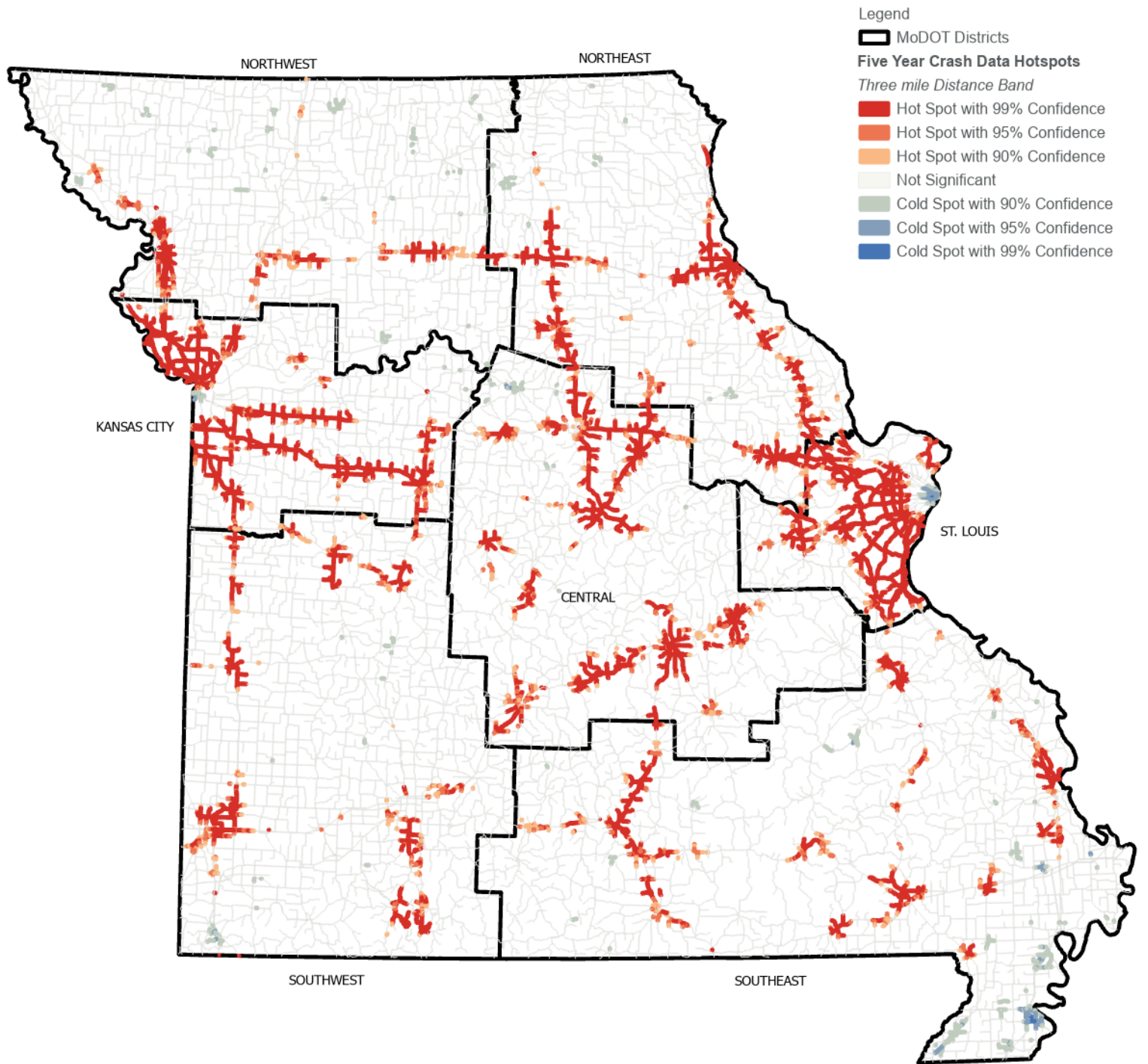
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



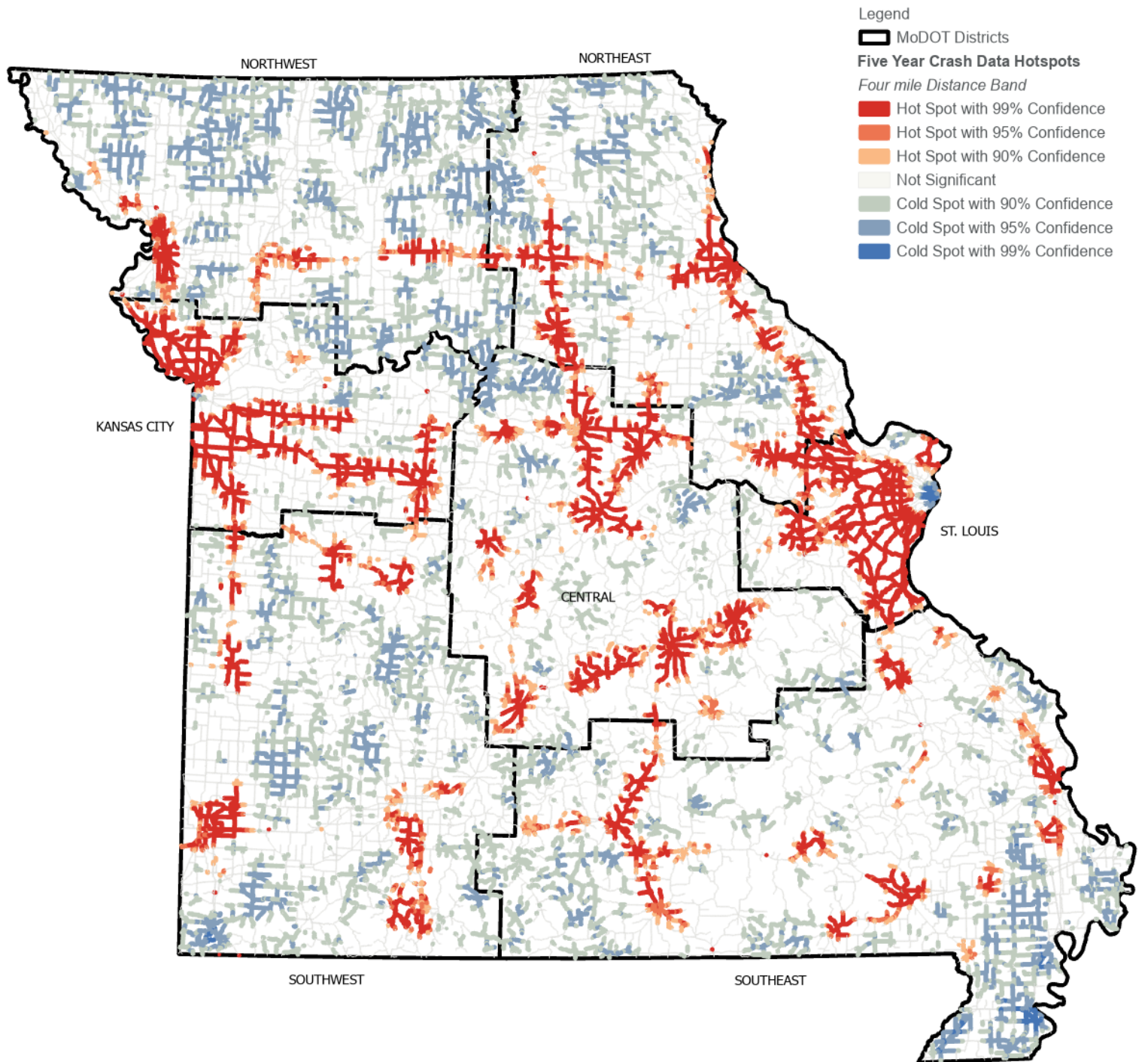
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



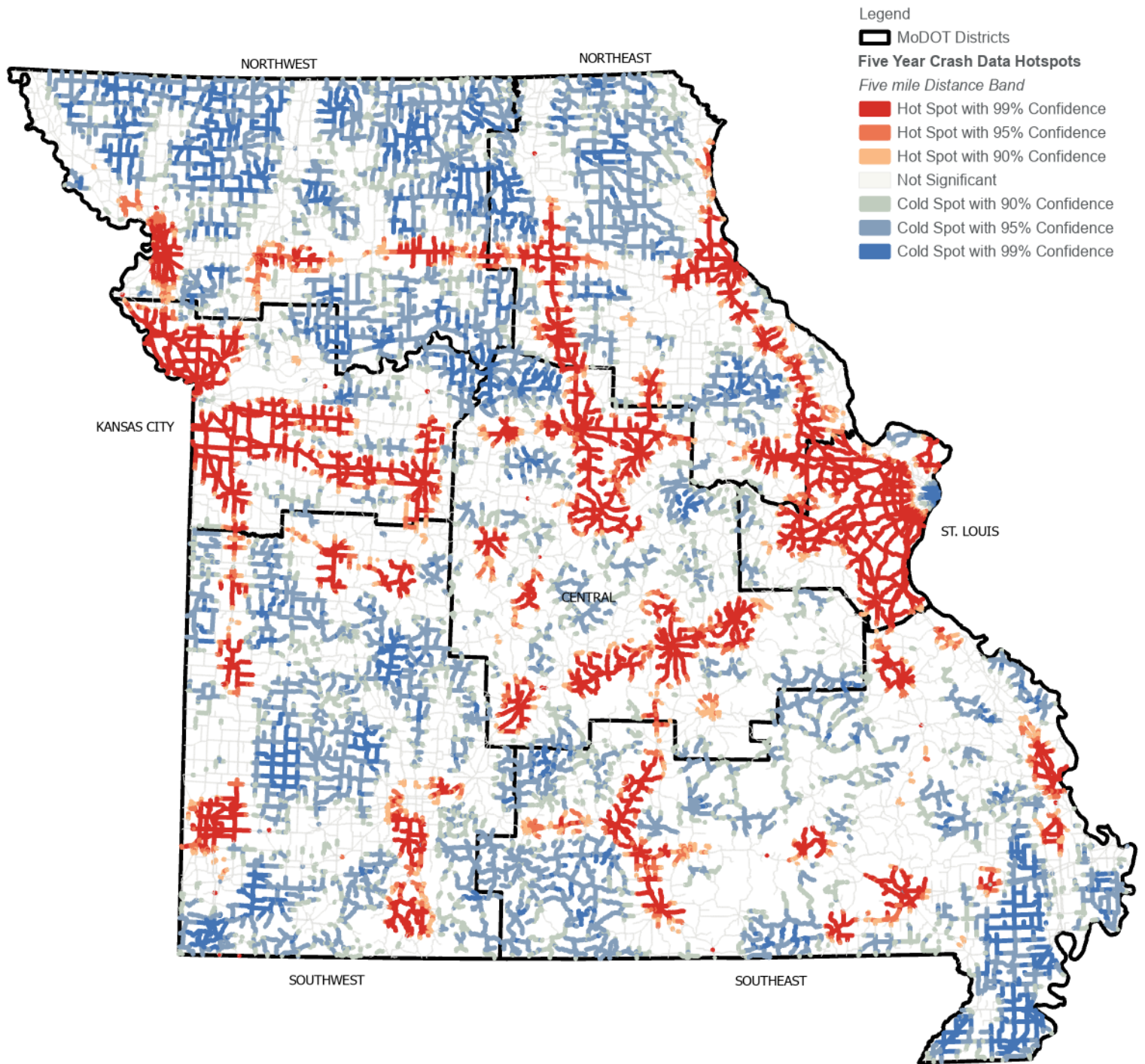
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



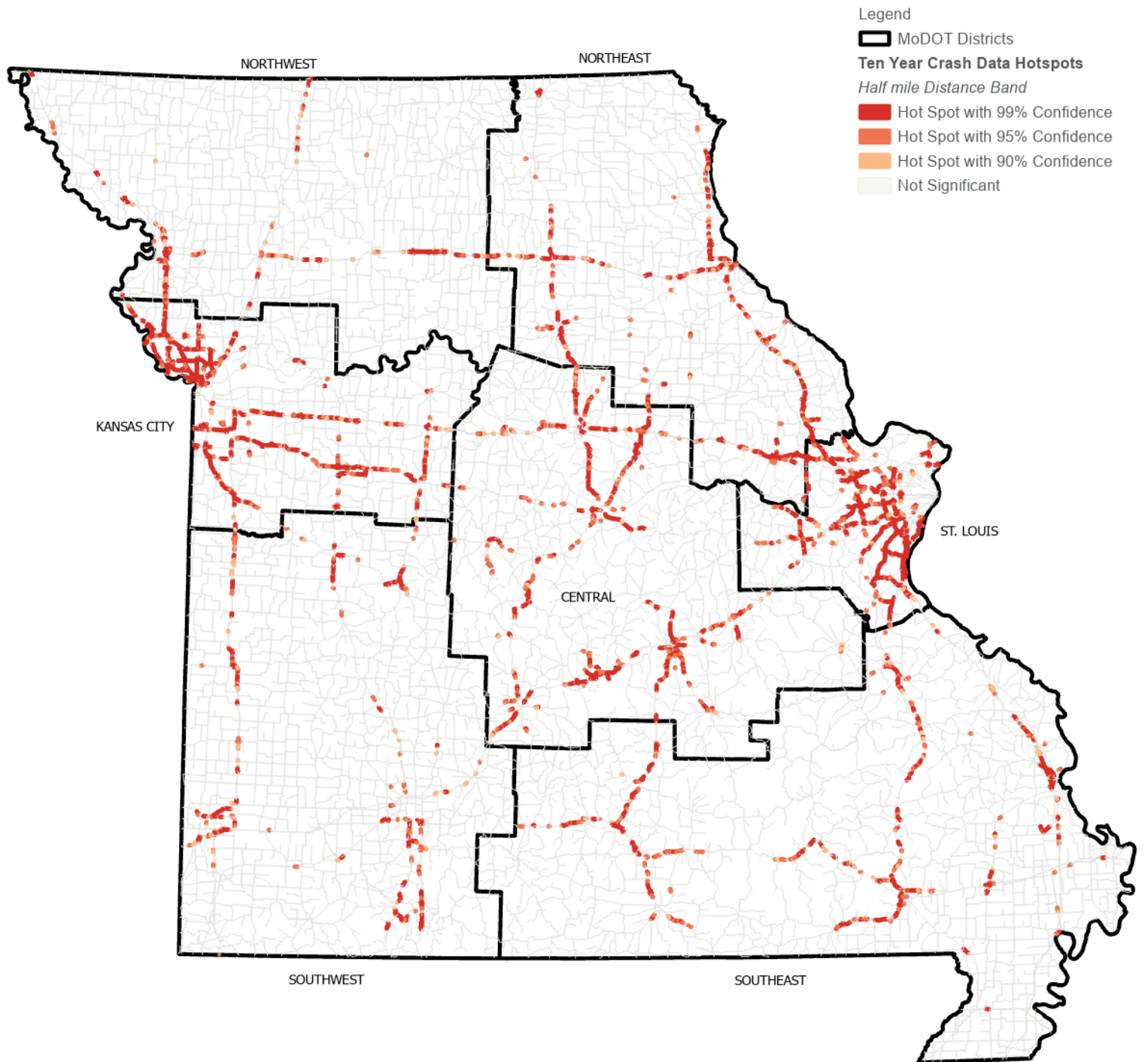
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



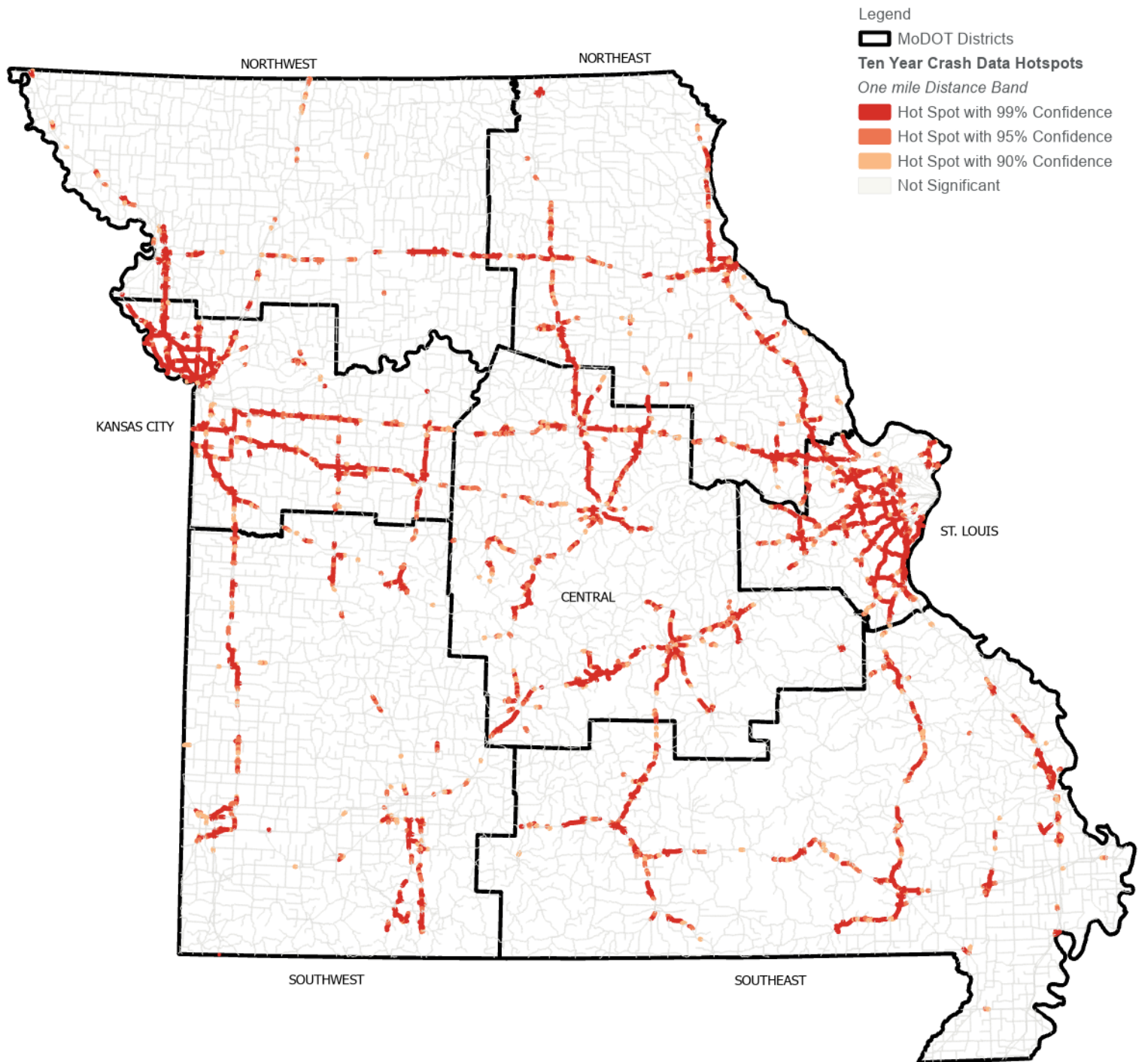
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



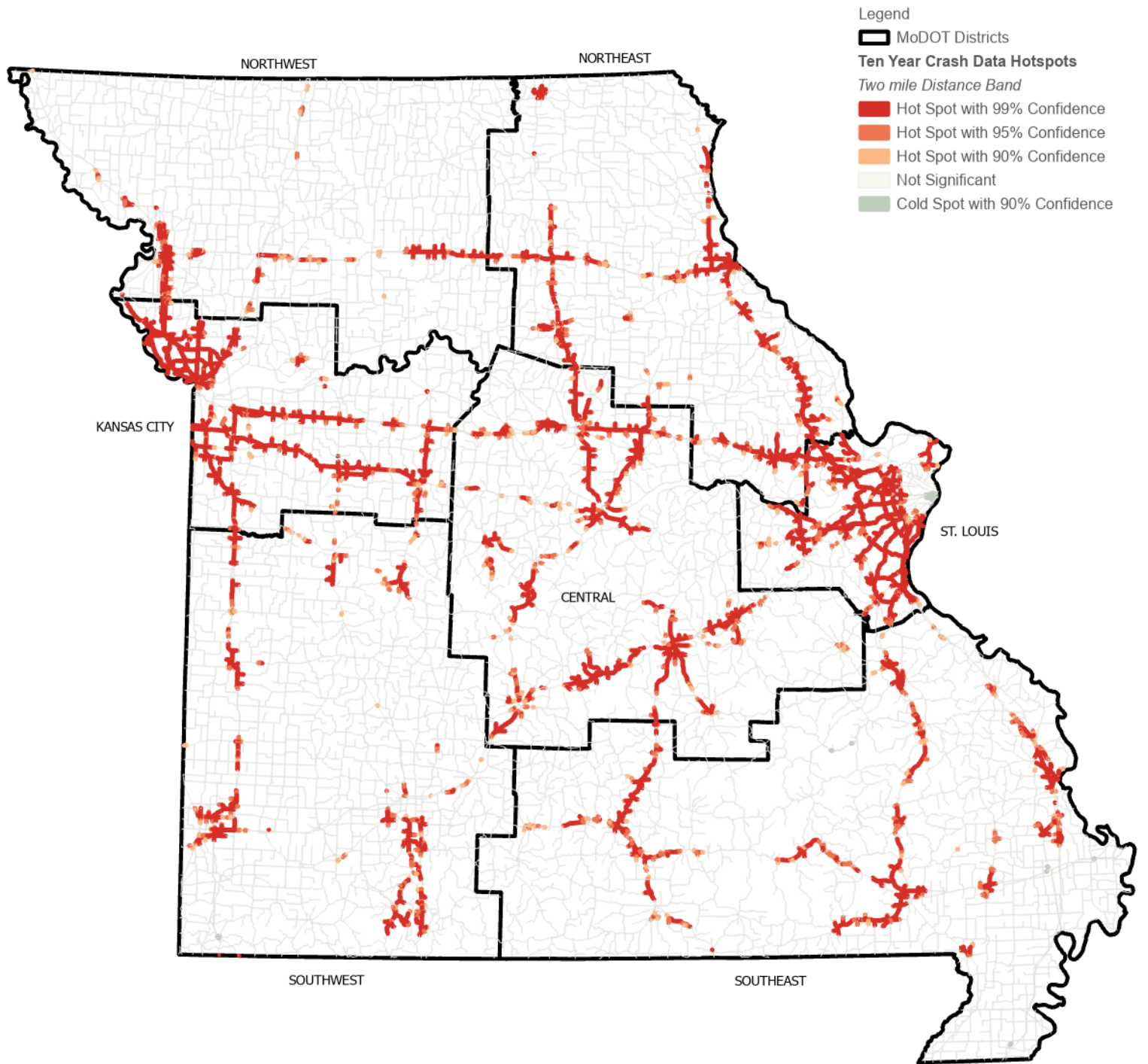
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



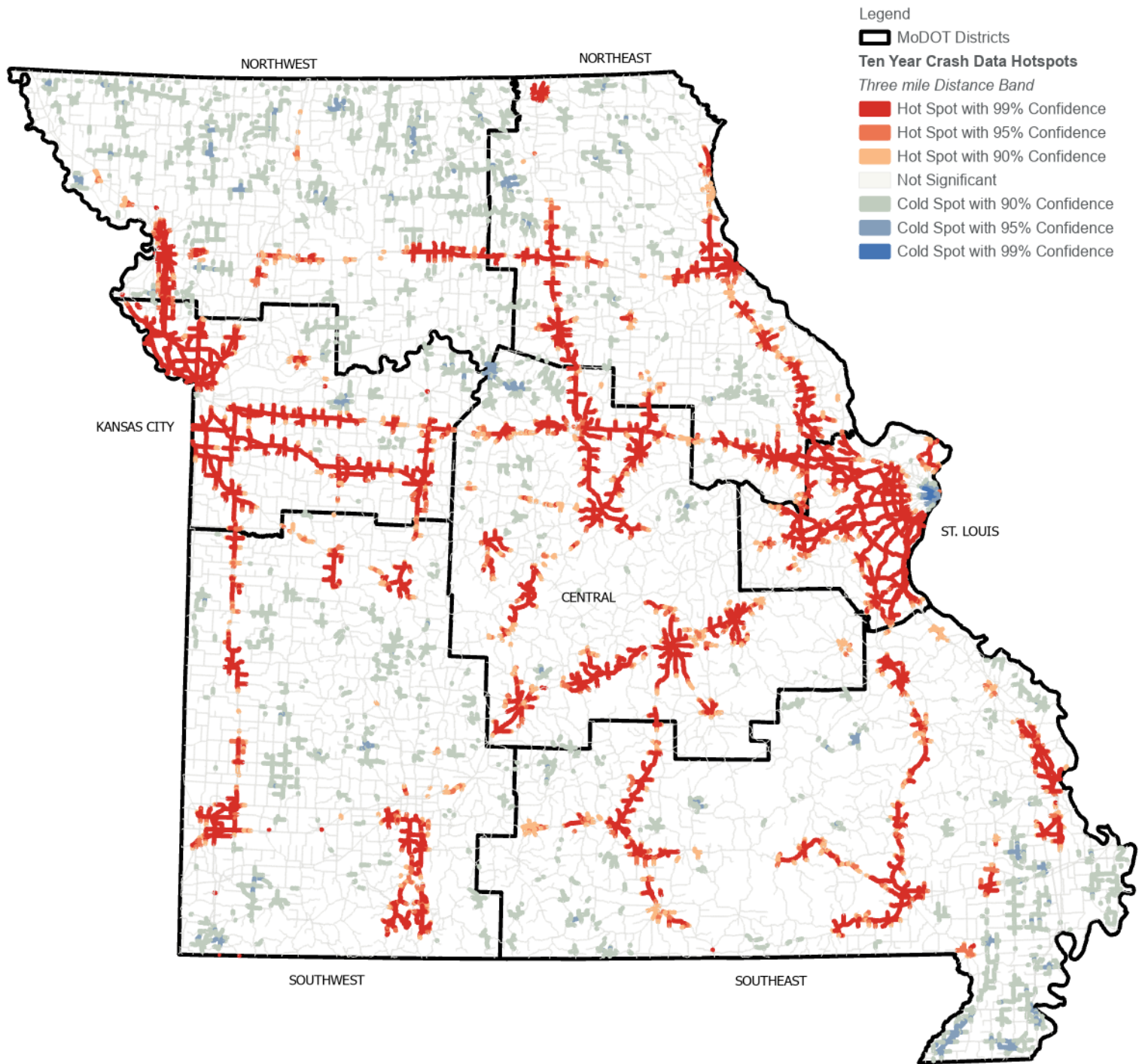
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



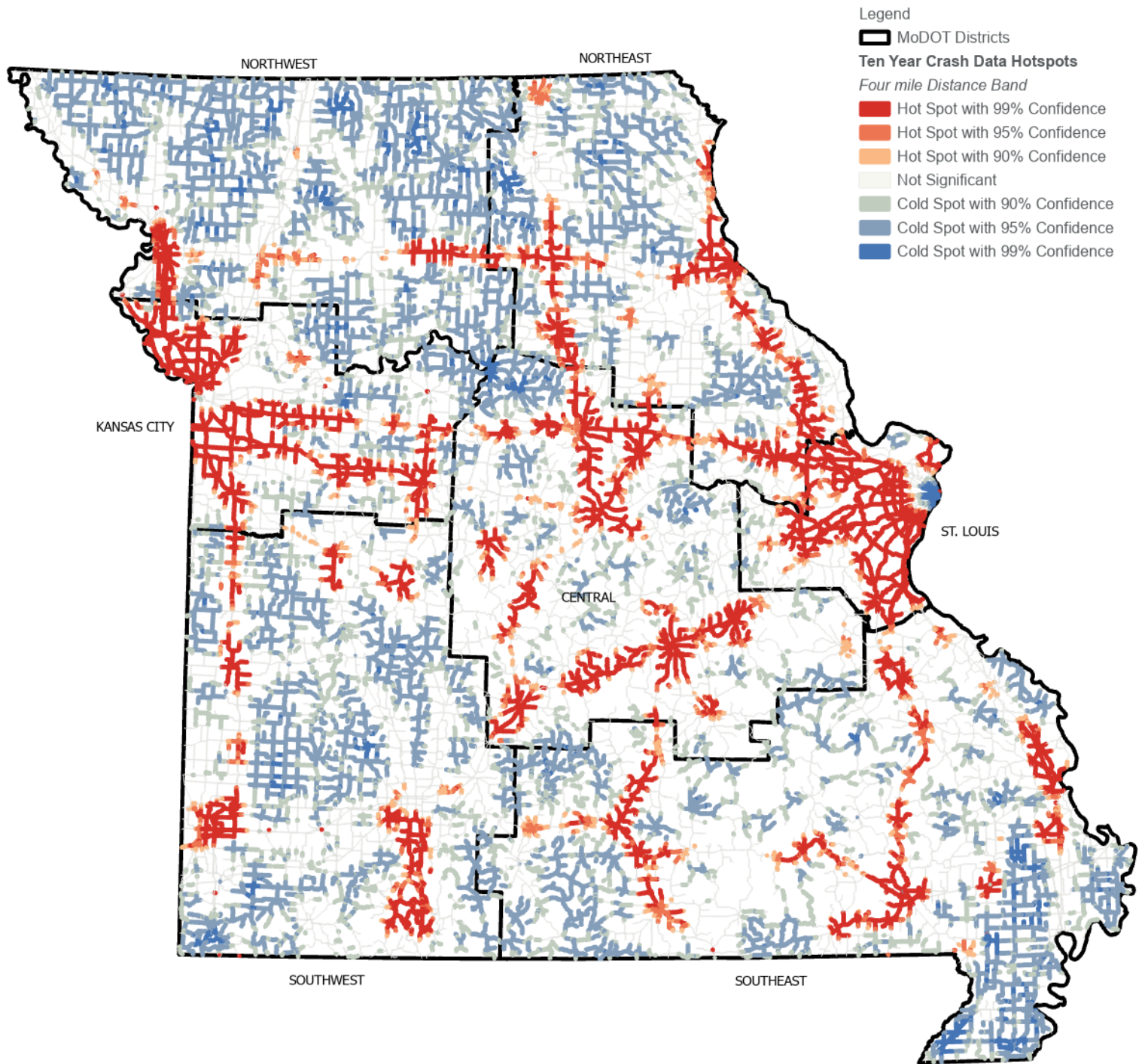
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Missouri State Highway Patrol WVC Optimized Hotspot Analysis



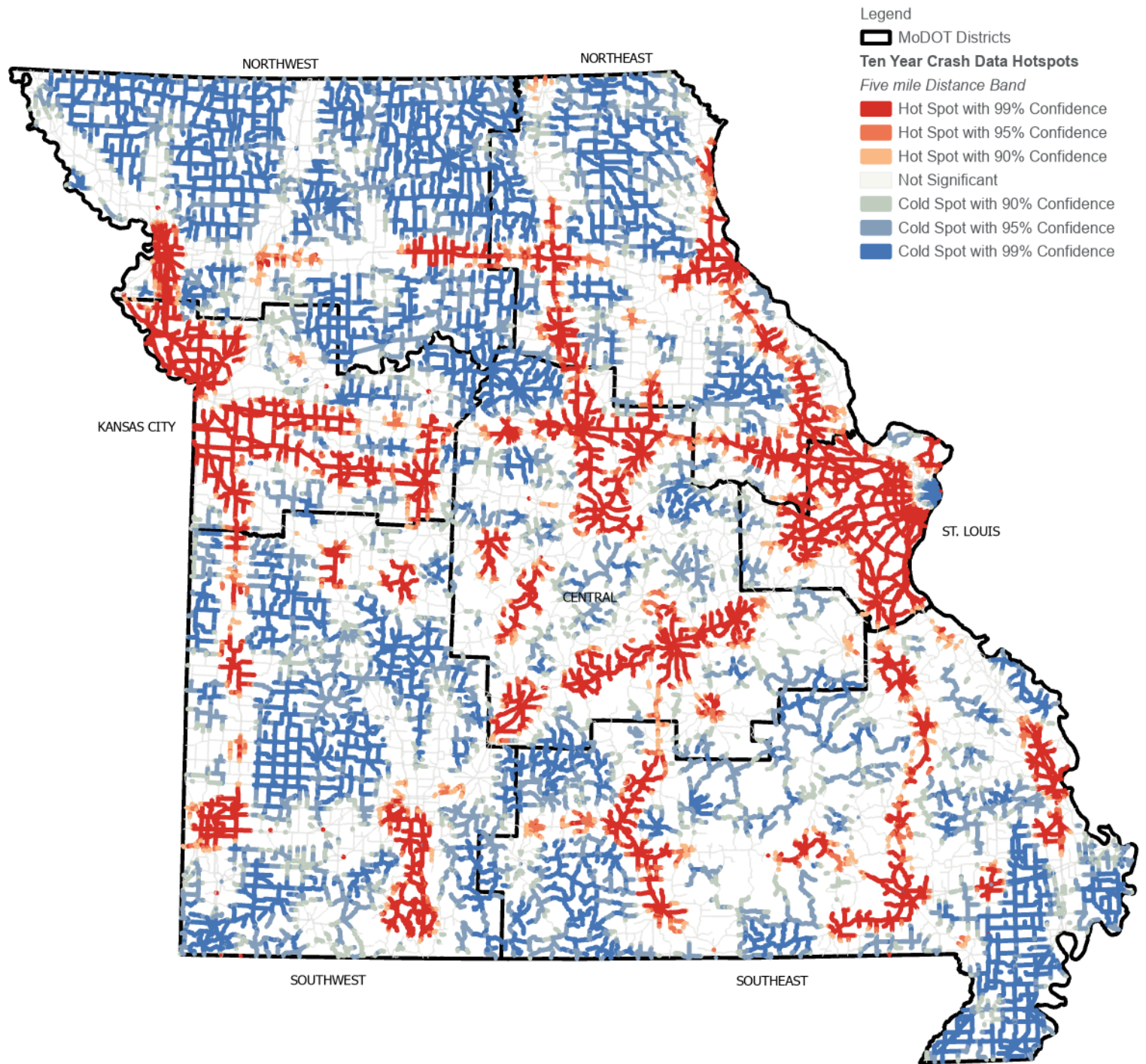
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Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



0 100 mi



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Missouri State Highway Patrol WVC Optimized Hotspot Analysis



0 100 mi



D

Predicted and Occupied Priority Species Habitat Development and Figures

MoDOT Priority Species Suitable Habitat Layer Development

Species	Habitat Description	MDC Habitats	Data Used	Methodology
			Plants	
Pondberry	Bottomlands & forested wetlands	Forests Woodlands Wetlands Stream Edges & Riparian Zones	NLCD (Woody Wetlands & Deciduous Forest) Floodplains NWI (PFO) NWI Riparian	NWI data was queried to show only palustrine forested wetlands (PFO). NLCD data was queried to show only woody wetlands and deciduous forest. The Intersect tool was used to select areas of deciduous forest layer within the queried NWI, floodplains, and NWI Riparian layers to show only bottomland forests and forested wetlands. The individual habitat layers were then merged together and dissolved into one combined habitat layer for pondberry.
			Birds	
Bald Eagle	Lakes, rivers, & marshes. Nest in forests & cliffs within 2 miles of large waterbodies	Forests Woodlands Cliffs Wetlands Lakes, Ponds, & Reservoirs Rivers & Streams Stream Edges & Riparian Zones	NLCD (Open Water, Deciduous Forest, Evergreen Forest, Mixed Forest, & Emergent Herbaceous Wetlands) NWI (PEM & PUB) NHD MDC Natural Heritage (Cliffs)	NLCD was queried to show open water, deciduous forest, evergreen forest, mixed forest, and emergent herbaceous wetlands. Select by Location was used to select forested areas within 2 miles of open water or NHD features, and to select emergent wetlands within 2 miles of forested areas. NWI data was queried to show palustrine unconsolidated bottom (PUB) and palustrine emergent (PEM) features. Select by Location was used to select PEM features within 2 miles of forested areas. MDC Natural Heritage data was queried to only show cliffs. Select by Location was also used to select cliffs within 2 miles of open waters or NHD features. The resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the bald eagle.
			Fish	
Niangua Darter	Creeks & streams	Rivers & Streams	NHD	The NHD layer was added to the map to be used as the Niangua darter habitat layer.
Topeka Shiner	Upland creeks	Rivers & Streams	NHD MDC Natural Heritage (Known Range)	Floodplain data queried to only show Flood Zone A was added to the map, and Select by Location was used to select all the NHD areas outside of floodplains. The resulting selection layer was exported as a feature class and the floodplain layer was removed from the map. MDC Natural Heritage data was queried to show the current known range of the Niangua darter.
			Amphibians	
Great Plains Toad	Floodplains, flooded fields, & roadside ditches along the Missouri River	Roadsides & Highly Disturbed Areas (roadside ditches) Wetlands Stream Edges & Riparian Zones	NLCD (Emergent Herbaceous Wetlands) Floodplains NWI (PEM)	NLCD was queried to show the emergent herbaceous wetland landcover type. NWI data was queried to show PEM wetlands. Floodplain data was queried to show Flood Zone A. Select by Location was used on the queried NLCD, NWI, and floodplain data to show features within 0.3 miles of the Missouri River (the dispersal distance of the great plains toad). The resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the great plains toad.
Northern Leopard Frog	Migrate between permanent waterbodies (wetlands, floodplains, ponds, lakes, & ditches) & grasslands/prairies	Prairies Savannas Wetlands Roadsides & Highly Disturbed Areas (ditches) Lakes, Ponds, & Reservoirs Stream Edges & Riparian Zones	NLCD (Open Water, Grassland/Herbaceous, Woody Wetlands, Emergent Herbaceous Wetlands) Floodplains NWI (PEM, PSS, PFO, PUB)	NLCD was queried to show open water, grassland/herbaceous, woody wetlands, and emergent herbaceous wetland landcover types. Floodplain data was queried to show Flood Zone A. NWI data was queried to show PEM, palustrine scrub/shrub (PSS), PFO, and PUB wetlands. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the northern leopard frog.
Eastern Tiger Salamander	Migrate between ponds/wetlands and savannas/prairies	Prairies, Savannas, Wetlands, Lakes, Ponds, & Reservoirs	NLCD (Open Water, Grasslands/Herbaceous, Woody Wetlands, Emergent Herbaceous Wetlands) NWI (PEM, PSS, PFO, PUB)	NLCD was queried to show open water, grassland/herbaceous, woody wetlands, and emergent herbaceous wetland landcover types. NWI data was queried to show PEM, PSS, PFO, and PUB wetlands. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the eastern tiger salamander.

MoDOT Priority Species Suitable Habitat Layer Development

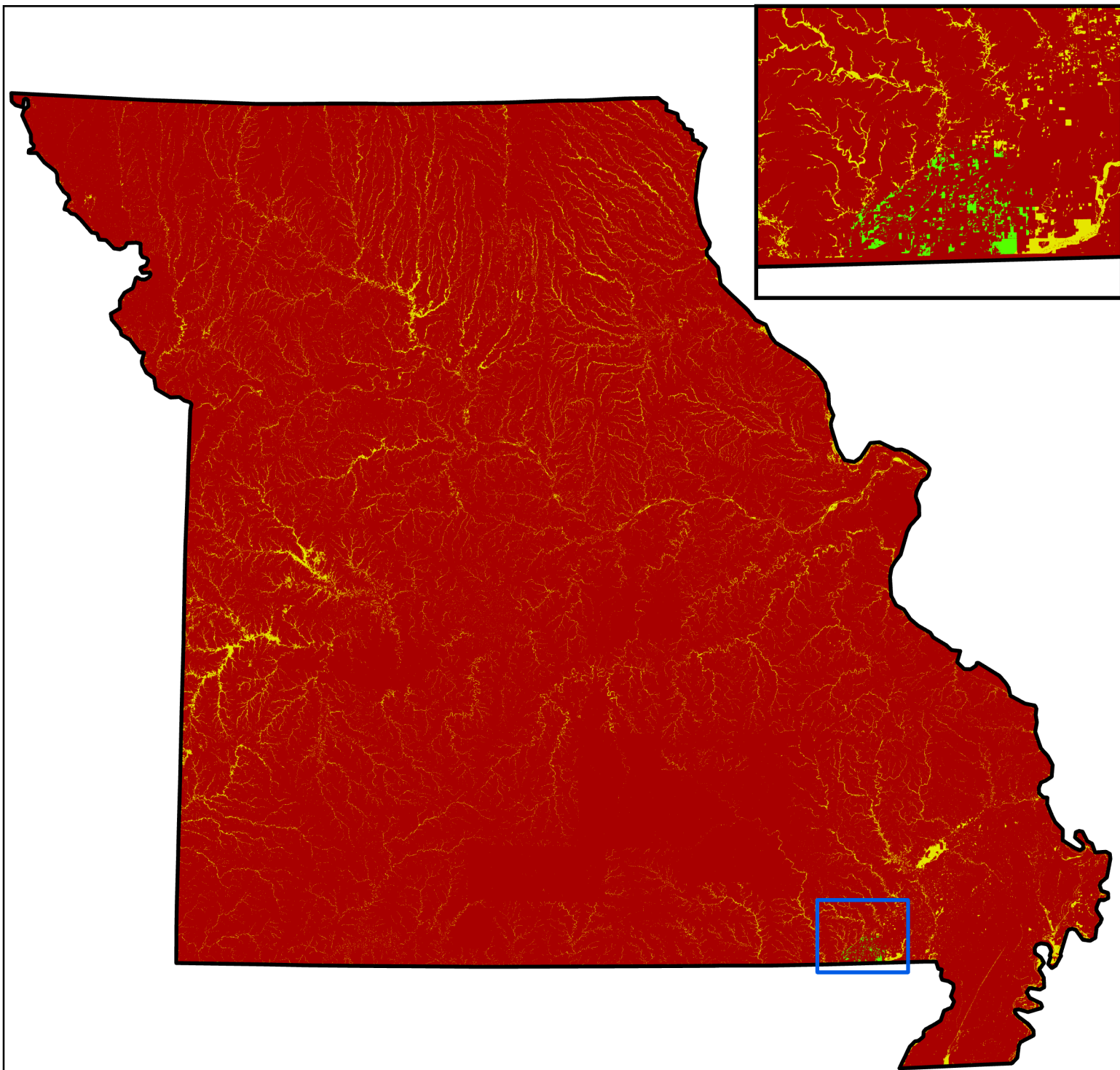
Species	Habitat Description	MDC Habitats	Data Used	Methodology
			Reptiles	
Alligator Snapping Turtle	Deep sloughs, oxbow lakes, deep pools in large rivers, reservoirs, & streams	Wetlands Lakes, Ponds, & Reservoirs Rivers & Streams	NLCD (Open Water, Woody Wetlands, Emergent Herbaceous Wetlands) NWI (PEM, PSS, PFO, PUB) NHD MDC Natural Heritage (Oxbows)	NLCD was queried to open water, woody wetlands, and emergent herbaceous wetlands. NWI data was queried to show PEM, PSS, PFO, and PUB. MDC Natural Heritage data was queried to show oxbows and NHD data was added to the map. The individual habitat layers were then merged together and dissolved into one combined habitat layer.
Blanding's Turtle	Prairies, grasslands, wetlands, ponds, & drainage ditches	Prairies Savannas Wetlands Lakes, Ponds, & Reservoirs Roadsides & Highly Disturbed Areas (ditches)	NLCD (Open Water, Grassland/Herbaceous, Woody Wetlands, Emergent Herbaceous Wetlands) NWI (PEM, PSS, PFO, PUB)	NLCD was queried to show open water, grassland/herbaceous, woody wetlands, and emergent herbaceous wetlands. NWI data was queried to show PEM, PSS, PFO, and PUB wetlands. Select by Location was used to select queried NLCD and NWI data within 2.2 miles of grasslands (dispersal distance of Blanding's turtles). The resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for Blanding's turtle.
Western Chicken Turtle	River oxbows, lakes, swamps, wetlands, & bottomland forests	Forests Wetlands Lakes, Ponds, & Reservoirs Stream Edges & Riparian Zones	NLCD (Open Water, Deciduous Forest, Evergreen Forest, Mixed Forest, Emergent Herbaceous Wetlands) Floodplains NWI (PEM, PUB) NWI Riparian MDC Natural Heritage (Oxbows)	NLCD was queried to show open water, deciduous forest, evergreen forest, mixed forest, and emergent herbaceous wetlands landcover types. Floodplain data was queried to show only Flood Zone A. NWI data was queried to show PEM and PUB wetlands, and the NWI Riparian layer was added to the map. The MDC Natural Heritage layer was queried to show oxbows. The Select by Location tool was used to select deciduous, evergreen, and mixed forests within floodplains and riparian areas, and the resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for Blanding's turtle.
Western Foxsnake	Prairies, grasslands, & forest edges adjoining wetlands and floodplains	Prairies Savannas Wetlands Stream Edges & Riparian Zones	NLCD (Scrub/Shrub, Grassland/Herbaceous, Woody Wetlands, Emergent Herbaceous Wetlands) Floodplains NWI (PEM, PSS, PFO)	NLCD was queried to show scrub/shrub, grassland/herbaceous, woody wetlands, and emergent herbaceous wetlands landcover types. Floodplain data was queried to show only Flood Zone A. NWI data was queried to only show PEM, PSS, PFO, and PUB wetlands. The Select by Location tool was used to select scrub/shrub and grassland/herbaceous areas within 0.9 miles of floodplains or wetlands (dispersal distance of western foxsnakes). The individual habitat layers were then merged together and dissolved into one combined habitat layer for the western foxsnake.
Western Mudsake	Bottomland forests, wetlands, swamps, stream edges, lakes, drainage ditches	Forests Woodlands Wetlands Lakes, Ponds, & Reservoirs Roadsides & Highly Disturbed Areas (ditches) Stream Edges & Riparian Zones	NLCD (Deciduous Forest) NWI (PFO, PUB) NWI Riparian MDC Natural Heritage (Swamps) Floodplains	NLCD was queried to show deciduous forest. NWI was queried to show PFO and PUB. Floodplain data was queried to only show Flood Zone A. MDC Natural Heritage data was queried to show swamps. The Select by Location tool was used to select only the PUB, queried floodplain, and NWI Riparian data within forested areas. The resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the western mudsnake.
Eastern Massasauga Rattlesnake	Wetlands, upland prairies, woodlands, forests	Prairies Savannas Forests Woodlands Wetlands	NLCD (Deciduous Forest, Evergreen Forest, Mixed Forest, Grassland/Herbaceous, Woody Wetlands, Emergent Herbaceous Wetlands) NWI (PEM, PSS, PFO)	NLCD was queried to show deciduous forest, evergreen forest, mixed forest, grassland/herbaceous, woody wetlands, and emergent herbaceous wetland landcover data. Floodplain data queried to only show Flood Zone A was added to the map, and Select by Location was used to select all the grassland areas outside of floodplains. The resulting selection layer was exported as a feature class and the floodplain layer was removed from the map. NWI data was queried to show PEM, PSS, and PFO wetlands. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the eastern massauga rattlesnake.
Kirtland's Snake	Bottomland prairies & grasslands, roadside ditches, ROWs	Prairies Savannas Roadsides & Highly Disturbed Areas (ditches, ROWs)	NLCD (Grassland/Herbaceous)	NLCD was queried to show grassland/herbaceous landcover types. Floodplain data queried to only show Flood Zone A was added to the map, and Select by Location was used to select all the grassland areas outside of floodplains. The resulting selection layer was exported as a feature class and the floodplain layer was removed from the map. The MoDOT ROW layer was added to the map. The individual habitat layers were then merged together and dissolved into one combined habitat layers for Kirtland's snake.

MoDOT Priority Species Suitable Habitat Layer Development

Species	Habitat Description	MDC Habitats	Data Used	Methodology
			Small Mammals	
Indiana Bat	Deciduous forests, riparian zones, caves/karst	Forests Woodlands Caves/Karst Lakes, Ponds, & Reservoirs Rivers & Streams Stream Edges & Riparian Zones	NLCD (Deciduous Forest, Mixed Forest) NWI Riparian - forested MDC Natural Heritage (Caves/Karst)	NLCD was queried to show deciduous and mixed forest only. The intersection of forested areas and NWI Riparian areas was selected using Intersect, to show only forested riparian areas. MDC Natural Heritage data was queried to only show caves/karst. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the Indiana bat.
Black-Tailed Jackrabbit	Open plains, grasslands, pastures, cultivated crops, hay	Prairies Savannas Altered Grasslands Roadsides & Highly Disturbed Areas (crops)	NLCD (Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, & Cultivated Crops)	NLCD was queried to show shrub/scrub, grassland/herbaceous, pasture/hay, and cultivated crops landcover types. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the black-tailed jackrabbit.
Franklin's Ground Squirrel	Edge habitats along the transition from forest to grasslands (i.e. woodlands), ROWs	Prairies Savannas Woodlands Roadsides & Highly Disturbed Areas (ROWs)	NLCD (Scrub/Shrub, Deciduous Forest, Evergreen Forest, Mixed Forest, Grassland/Herbaceous)	NLCD was queried to show scrub/shrub, deciduous forest, evergreen forest, mixed forest, and grasslands. The Select by Location tool was used to select forested areas adjacent grasslands. The resulting selection layers were exported as feature classes. The individual habitat layers were then merged together and dissolved into one combined habitat layer for Franklin's ground squirrel.
Thirteen-Lined Ground Squirrel	Grasslands dominated by short grasses, including developed landscapes (golf courses, mowed ROWs)	Prairies Savannas Altered Grasslands Roadsides & Highly Disturbed Areas (ROWs & developed open spaces)	NLCD (Developed Open Space & Grassland/Herbaceous)	NLCD was queried to show developed open space and grassland/herbaceous landcover types. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the thirteen-lined ground squirrel.
Least Weasel	Short, sparse groundcover (pastures, harvested fields, marshes)	Prairies Savannas Altered Grasslands Wetlands Roadsides & Highly Disturbed Areas (crops)	NLCD (Pasture/Hay, Cultivated Crops, & Emergent Herbaceous Wetlands) NWI (PEM)	NLCD was queried to show pasture/hay, cultivated crops, and emergent herbaceous wetlands landcover types. NWI data was queried to only show PEM wetlands. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the least weasel.
Long-Tailed Weasel	Woodlands, brushy riparian corridors, fencerows	Prairies Savannas Woodlands Stream Edges & Riparian Zones	NLCD (Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub) NWI Riparian	NLCD was queried to show deciduous forests, evergreen forests, mixed forest, and shrub/scrub landcover types. The Interest tool was used to select NWI Riparian areas within forested and scrub/shrub landcovers. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the long-tailed weasel.

MoDOT Priority Species Suitable Habitat Layer Development

Species	Habitat Description	MDC Habitats	Data Used	Methodology
			Medium Mammals	
American Badger	Prairies, grasslands, agricultural land, pastures, & open, grassy developed areas (e.g. parks)	Prairies Altered Grasslands Roadsides & Highly Disturbed Areas (ROW & crops)	NLCD (Developed Open Space, Grassland/Herbaceous, Pasture/Hay, & Cultivated Crops)	NLCD was queried to show developed open space, grassland/herbaceous, pasture/hay, and cultivated crop landcover types. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the American badger.
Plains Spotted Skunk	Prairies, grasslands, agricultural lands, & shrubland	Prairies Savannas Forests Woodlands Altered Grasslands Roadsides & Highly Disturbed Areas (crops)	NLCD (Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, & Cultivated Crops)	NLCD was queried to show scrub/shrub, grassland/herbaceous, pasture/hay, and cultivated crops landcover types. The individual habitat layers were then merged together and dissolved into one combined habitat layer for the plains spotted skunk.
			Large Mammals	
White-Tailed Deer	Most habitats	Prairies Savannas Altered Grasslands Forests Woodlands Glades Wetlands Stream Edges & Riparian Zones Roadsides & Highly Disturbed Areas	NLCD (Developed Open Space, Developed Low Intensity, Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, Cultivated Crops, Woody Wetlands, & Emergent Herbaceous Wetlands) NWI Riparian MDC Natural Heritage (Glades)	NLCD was queried to show developed open space, developed low intensity, deciduous forest, evergreen forest, mixed forest, scrub/scrub, grassland/herbaceous, pasture/hay, cultivated crops, woody wetlands, and emergent herbaceous wetland landcover types. MDC Natural Heritage data was queried to show glades, and the MoDOT ROW and NWI Riparian layers were added to the map. The individual habitat layers were then merged together and dissolved into one combined habitat layer for white-tailed deer.
American Black Bear	Forested areas	Forests Woodlands	NLCD (Deciduous Forest, Evergreen Forest, Mixed Forest)	NLCD was queried to show deciduous forest, evergreen forest, and mixed forest landcover types. The individual habitat layers were then merged together and dissolved into one combined habitat layer for American black bear.
Elk	Woodlands, open forests, & pastures in Shannon, Carter, & Reynolds Counties	Altered Grasslands Forests Woodlands Glades	NLCD (Deciduous Forest, Evergreen Forest, Mixed Forest, Pasture/Hay) Glades	NLCD was queried to show deciduous forest, evergreen forest, mixed forest, and pasture/hay landcover types. MDC Natural Heritage data was queried to show only glades. The individual habitat layers were then clipped to Carter, Reynolds, and Shannon counties, merged together, and dissolved into one combined habitat layer for elk.

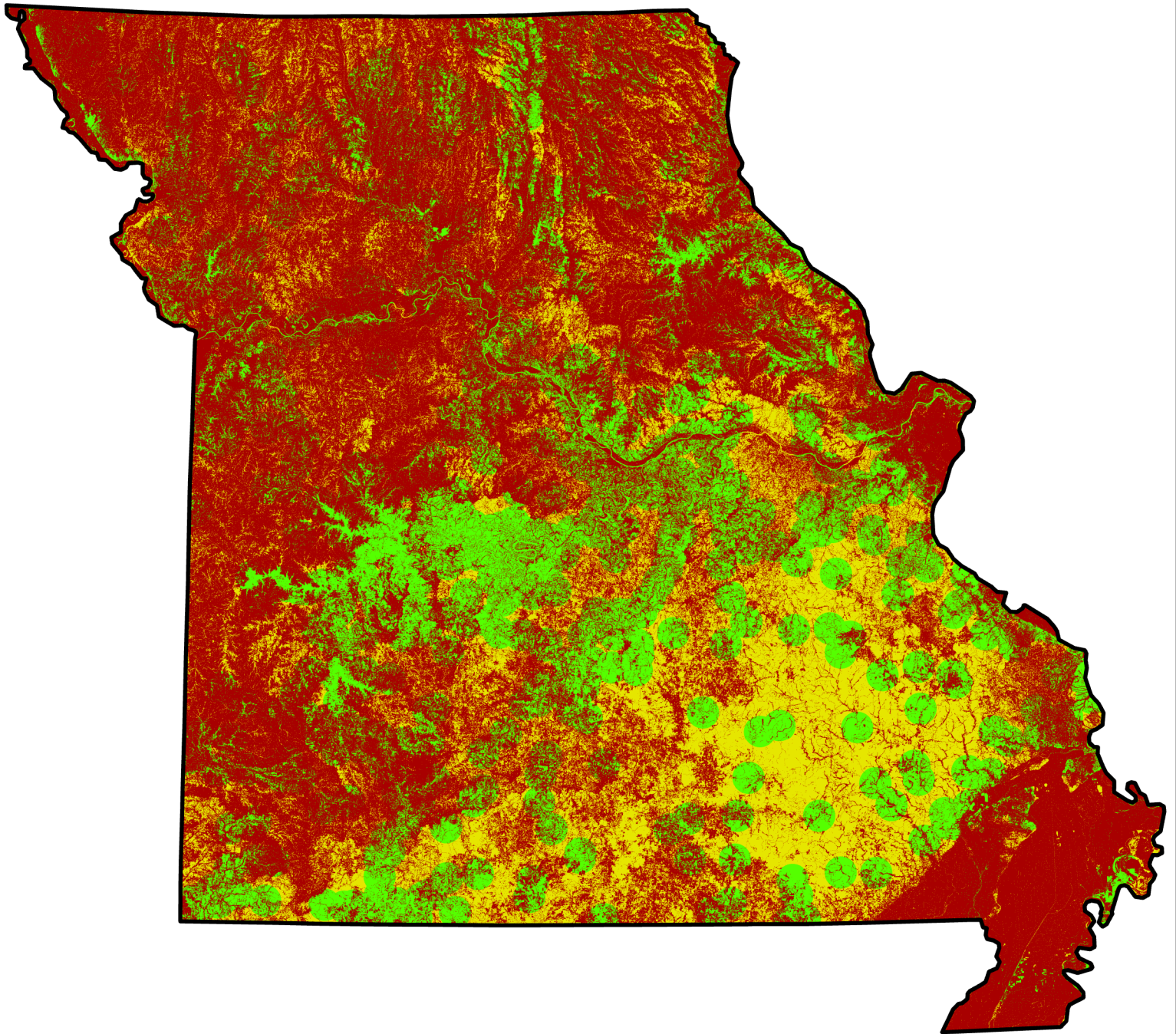


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 1: Pondberry Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

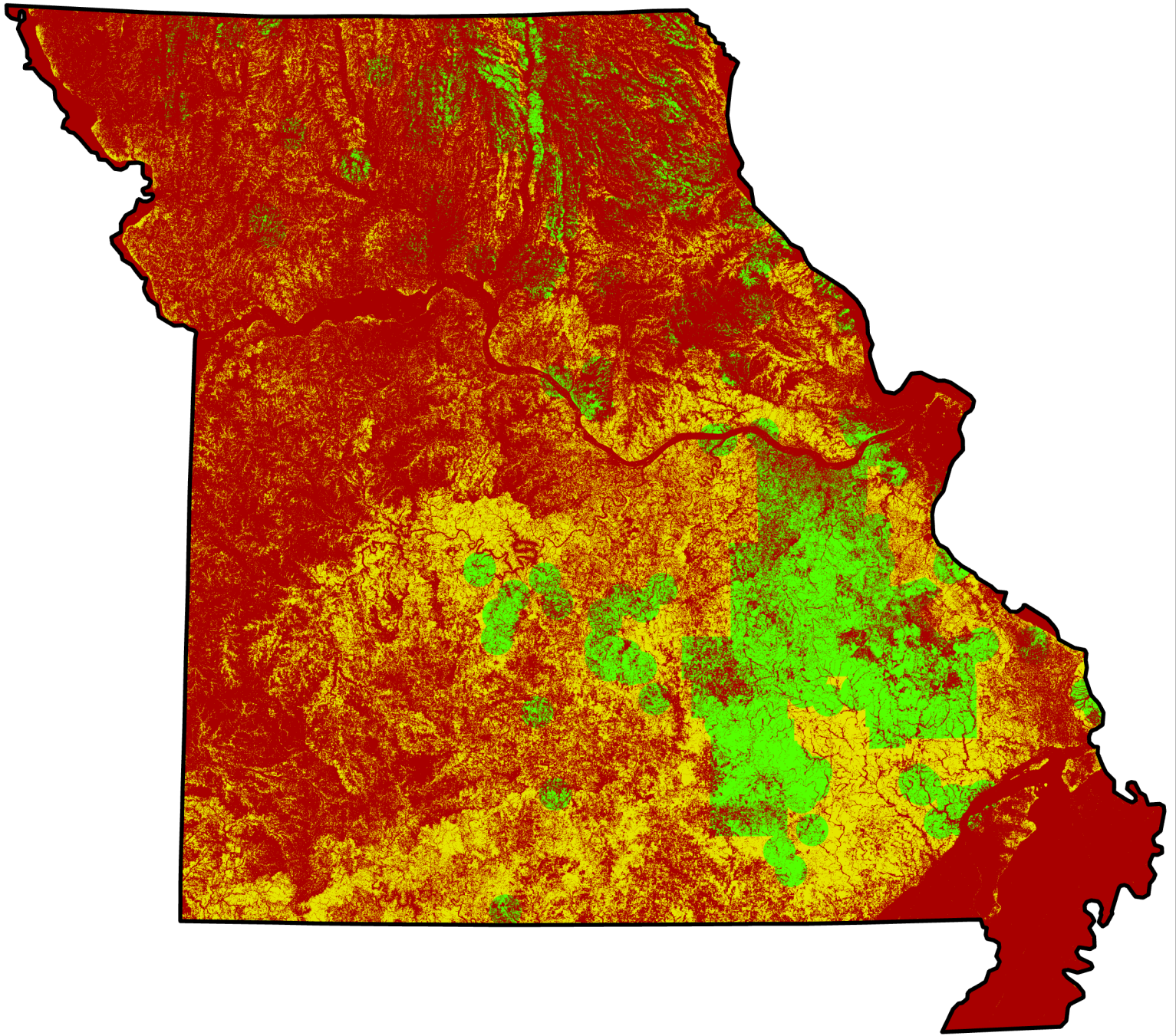


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 2: Bald Eagle Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

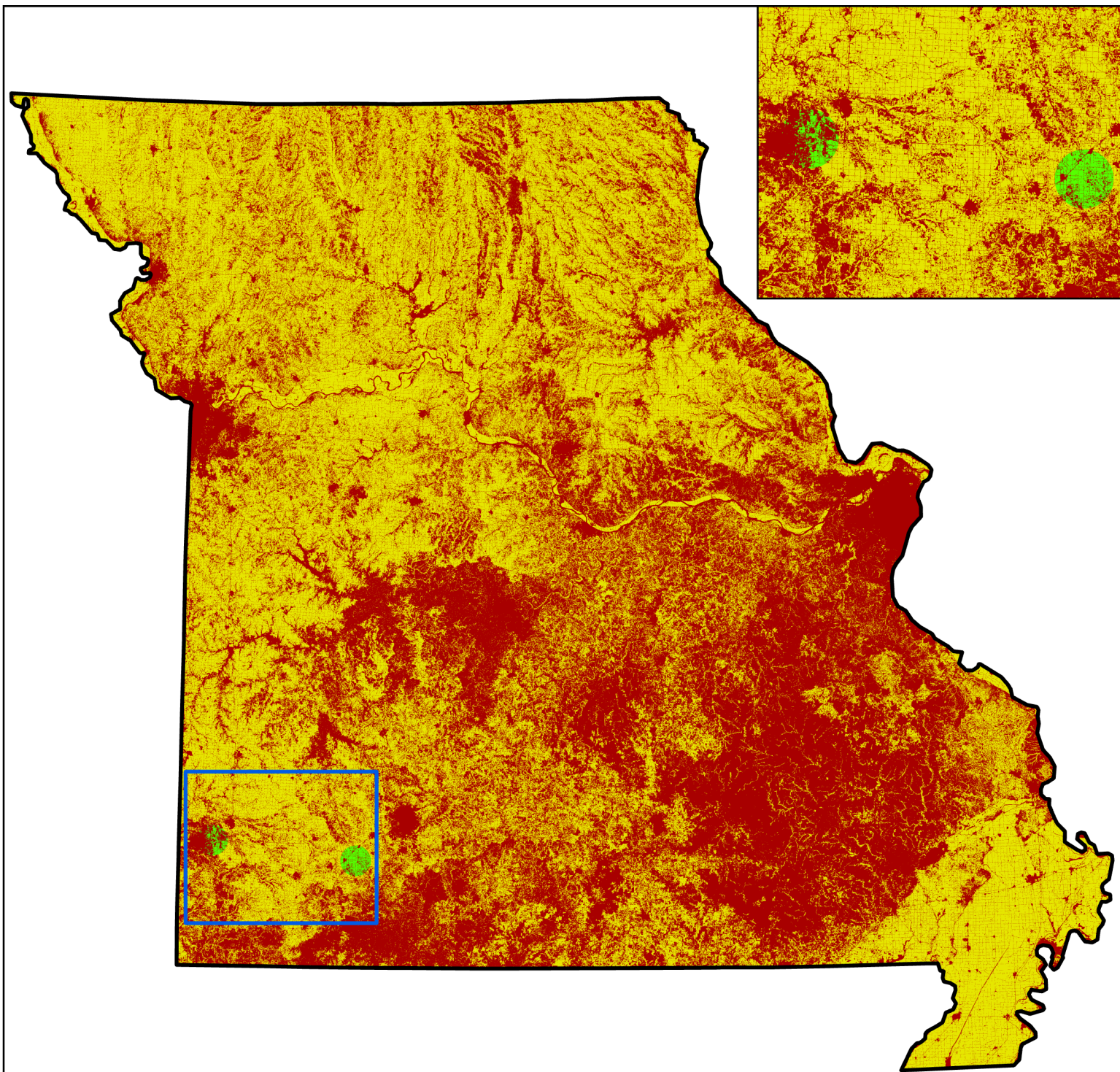


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 3 - Indiana Bat Habitat

 Occupied Habitat  Predicted Habitat  Unsuitable Habitat



0  100 mi

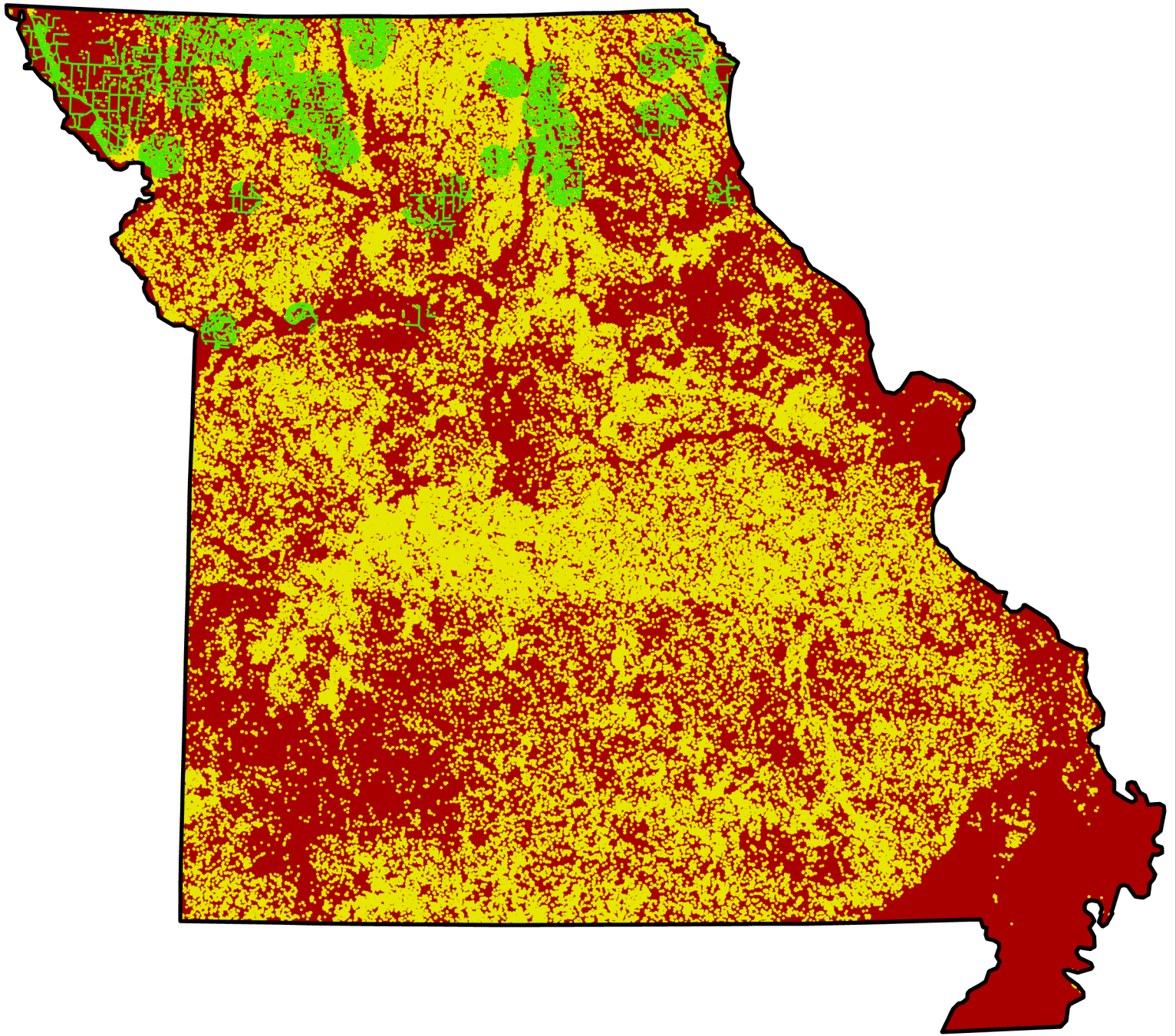


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 4: Black-Tailed Jackrabbit Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

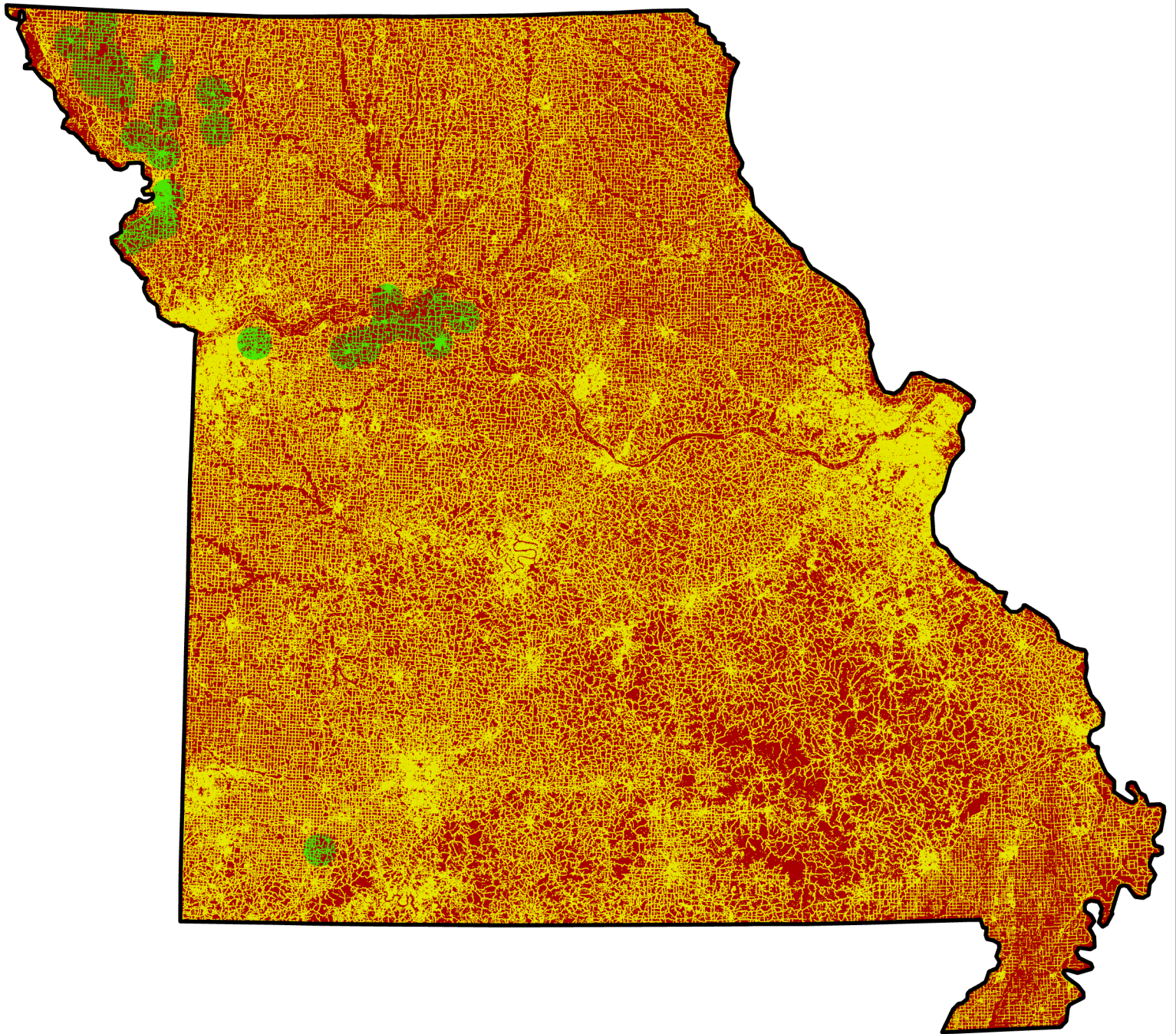


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 5: Franklin's Ground Squirrel Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

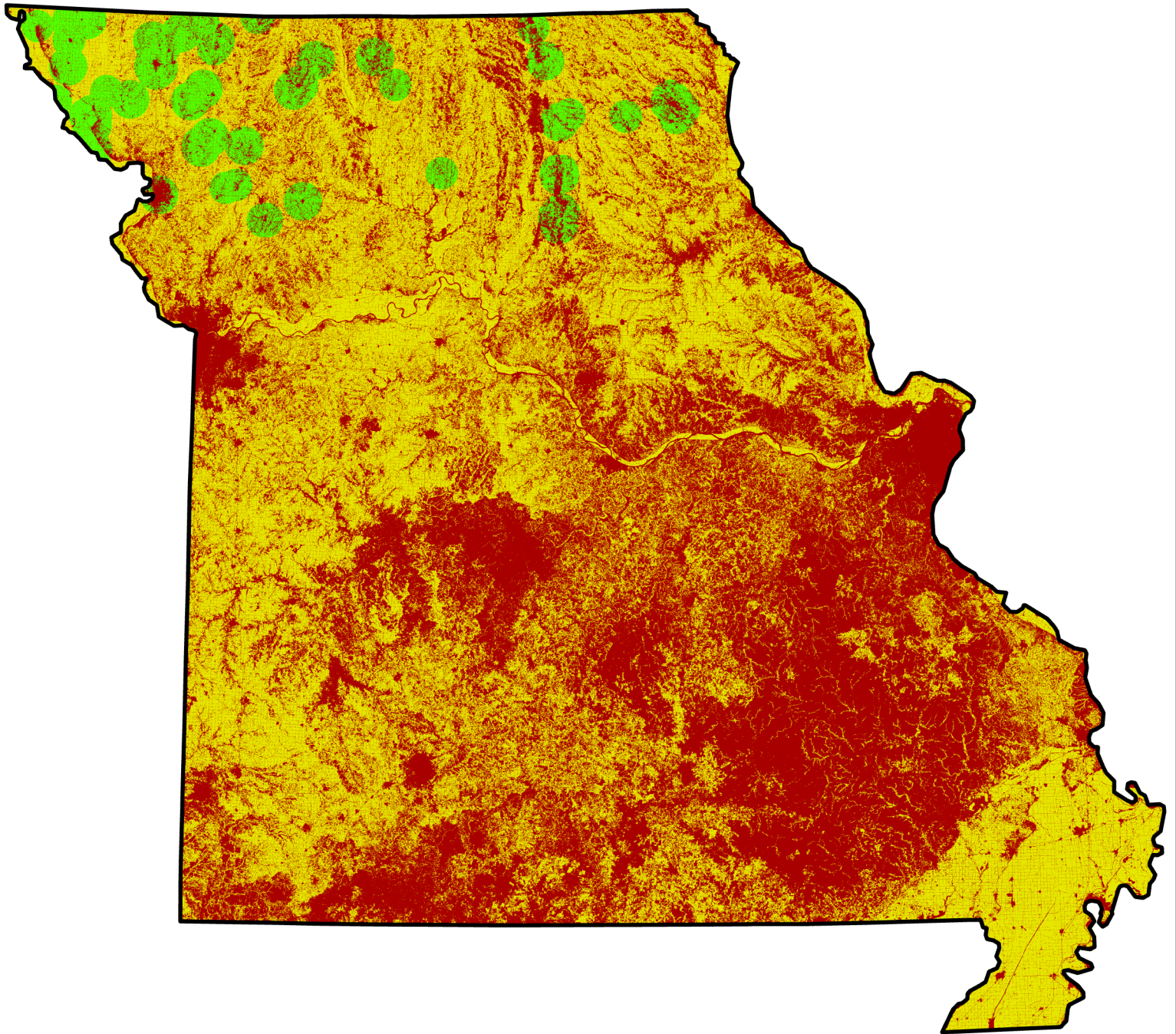


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 6: Thirteen-Lined Ground Squirrel Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



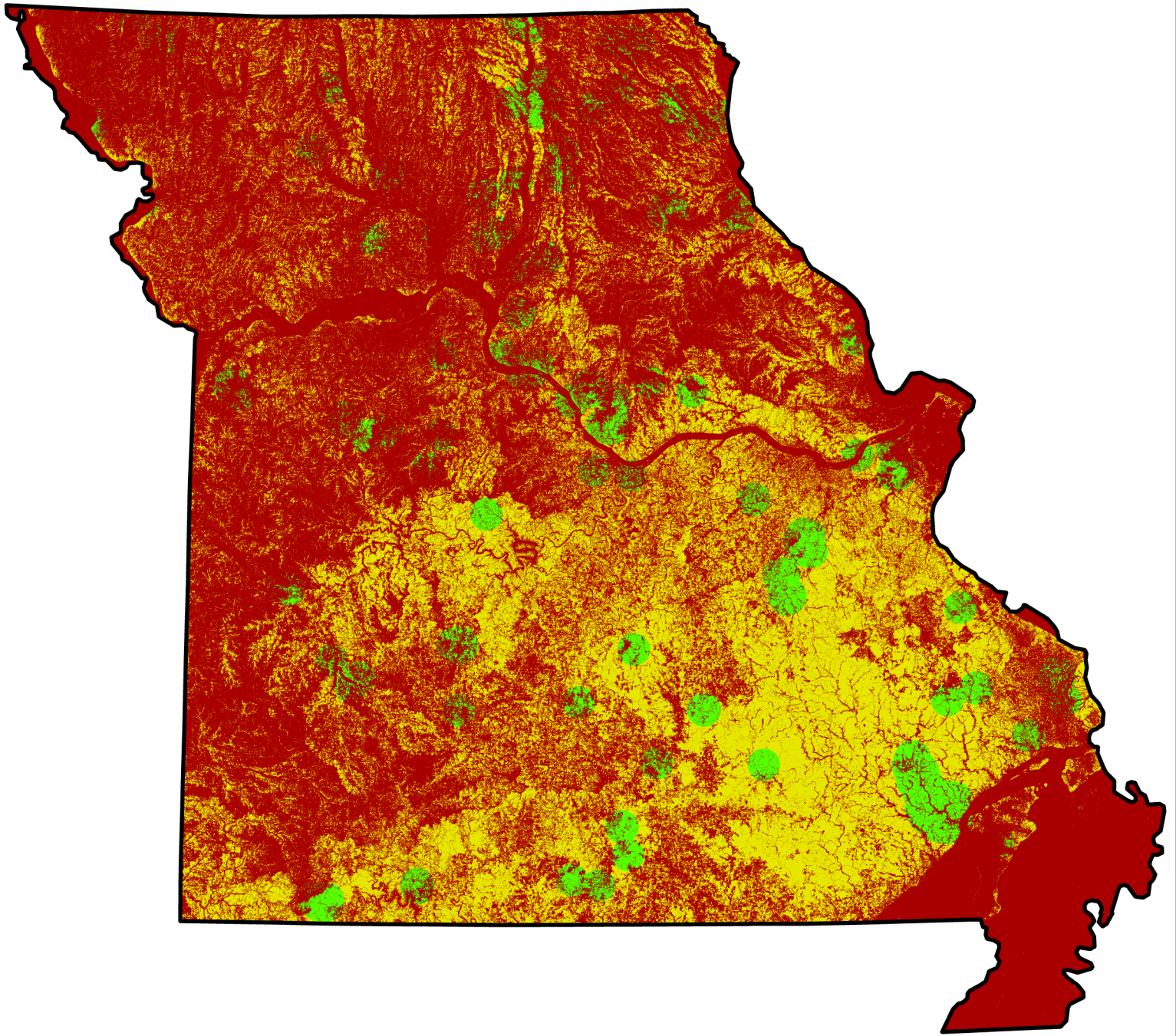
0 100 mi



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 7 - Least Weasel Habitat

 Occupied Habitat  Predicted Habitat  Unsuitable Habitat



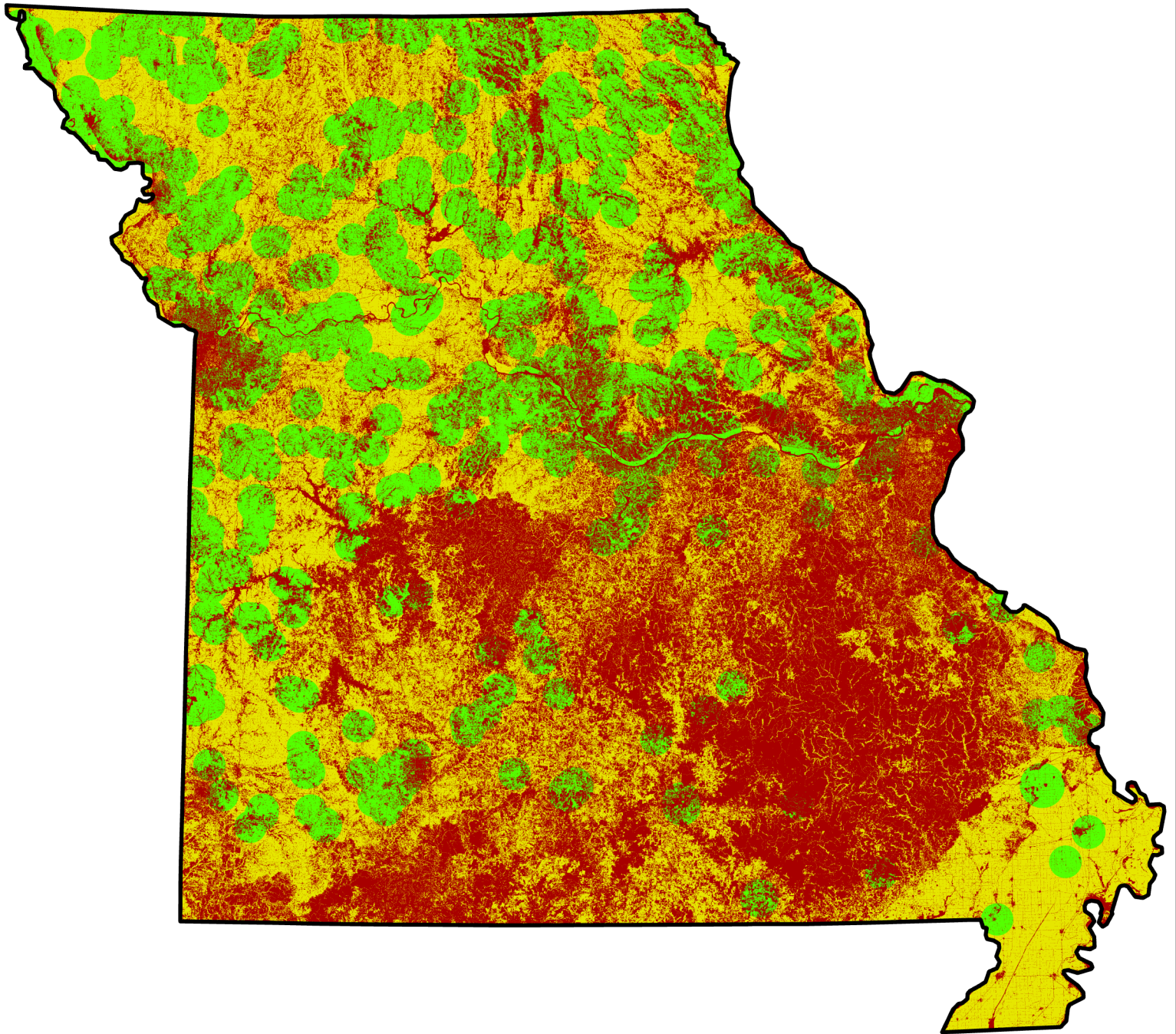


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 8: Long-Tailed Weasel Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

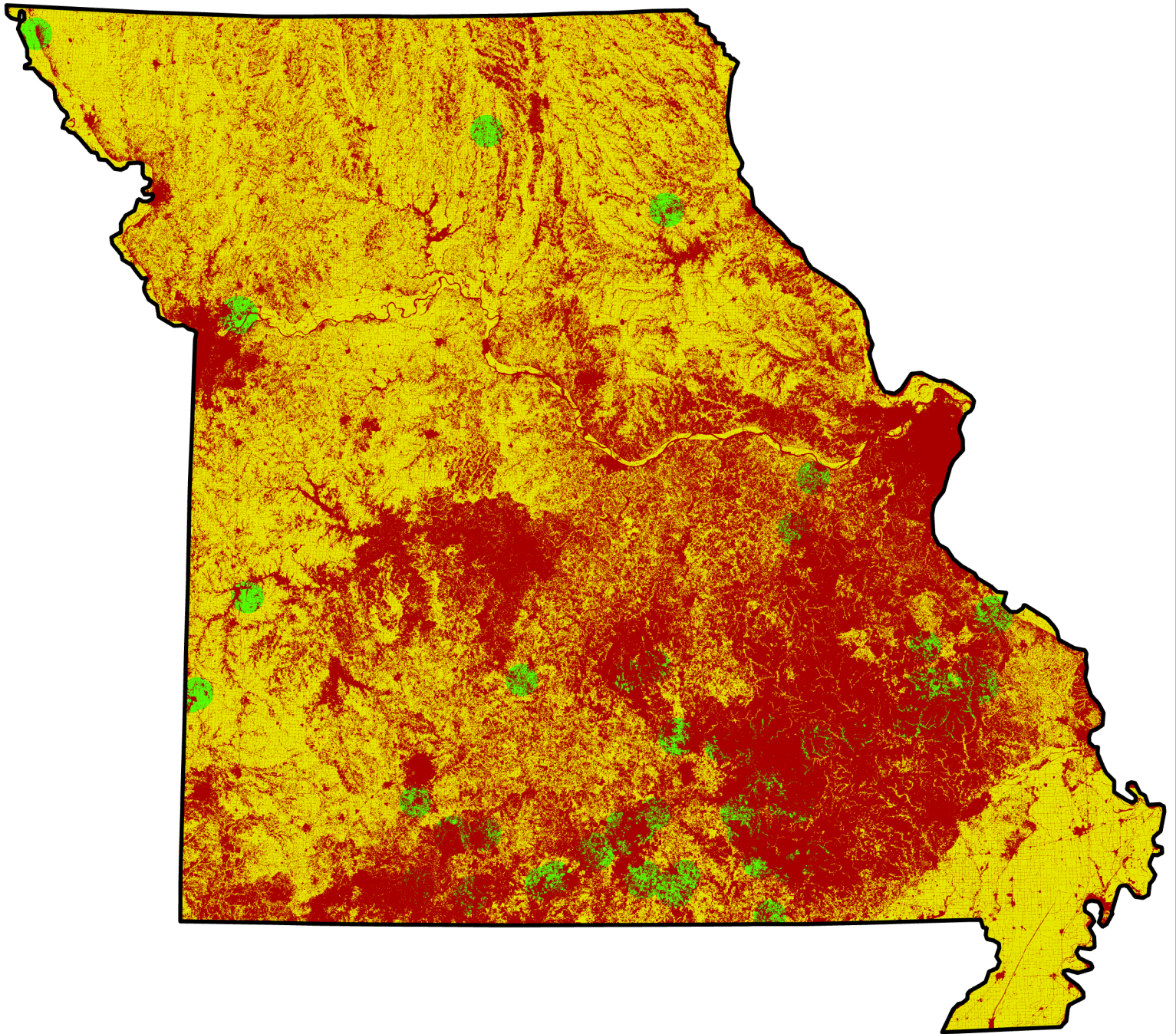


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 9 - American Badger Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

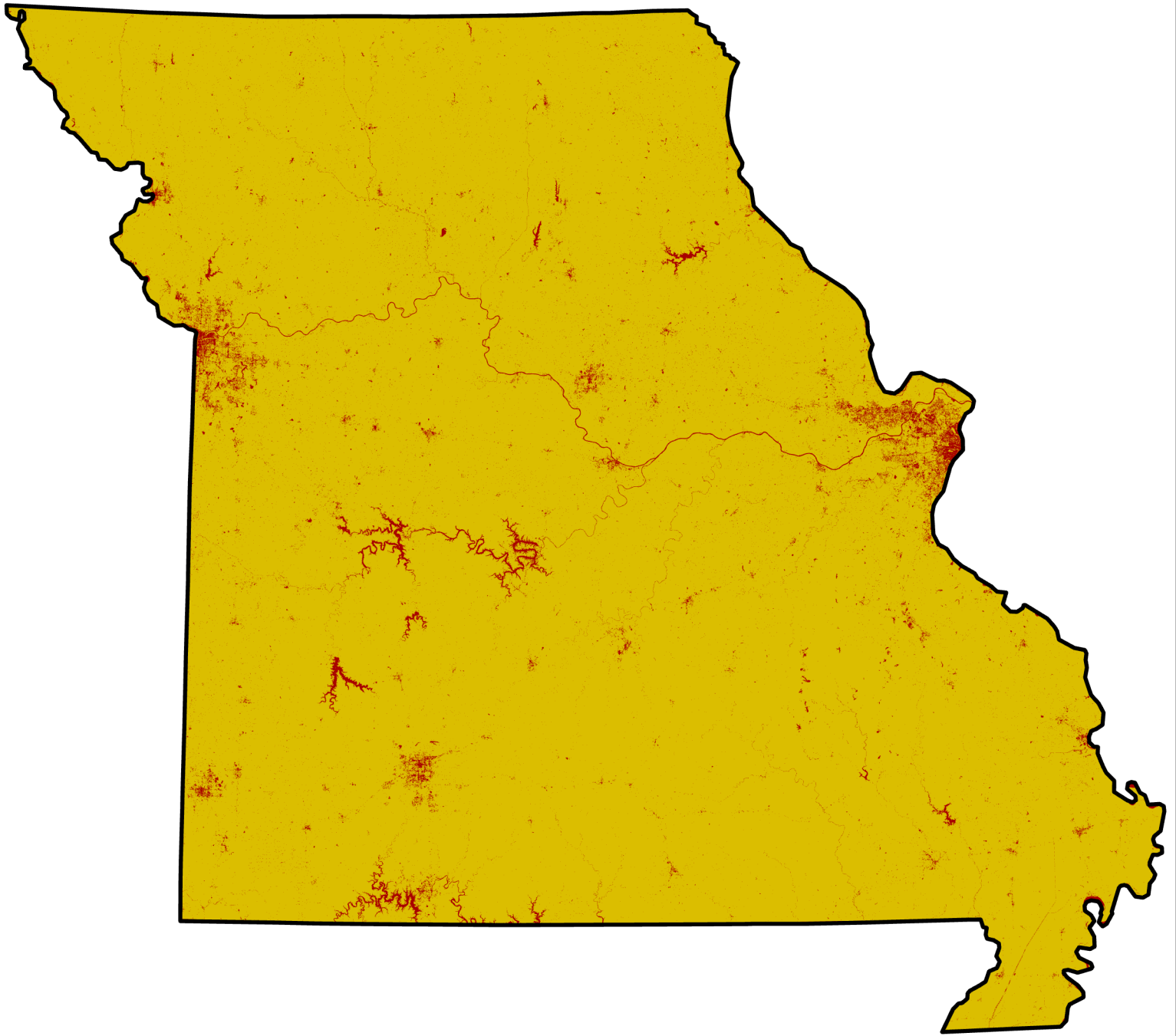


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 10: Plains Spotted Skunk Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

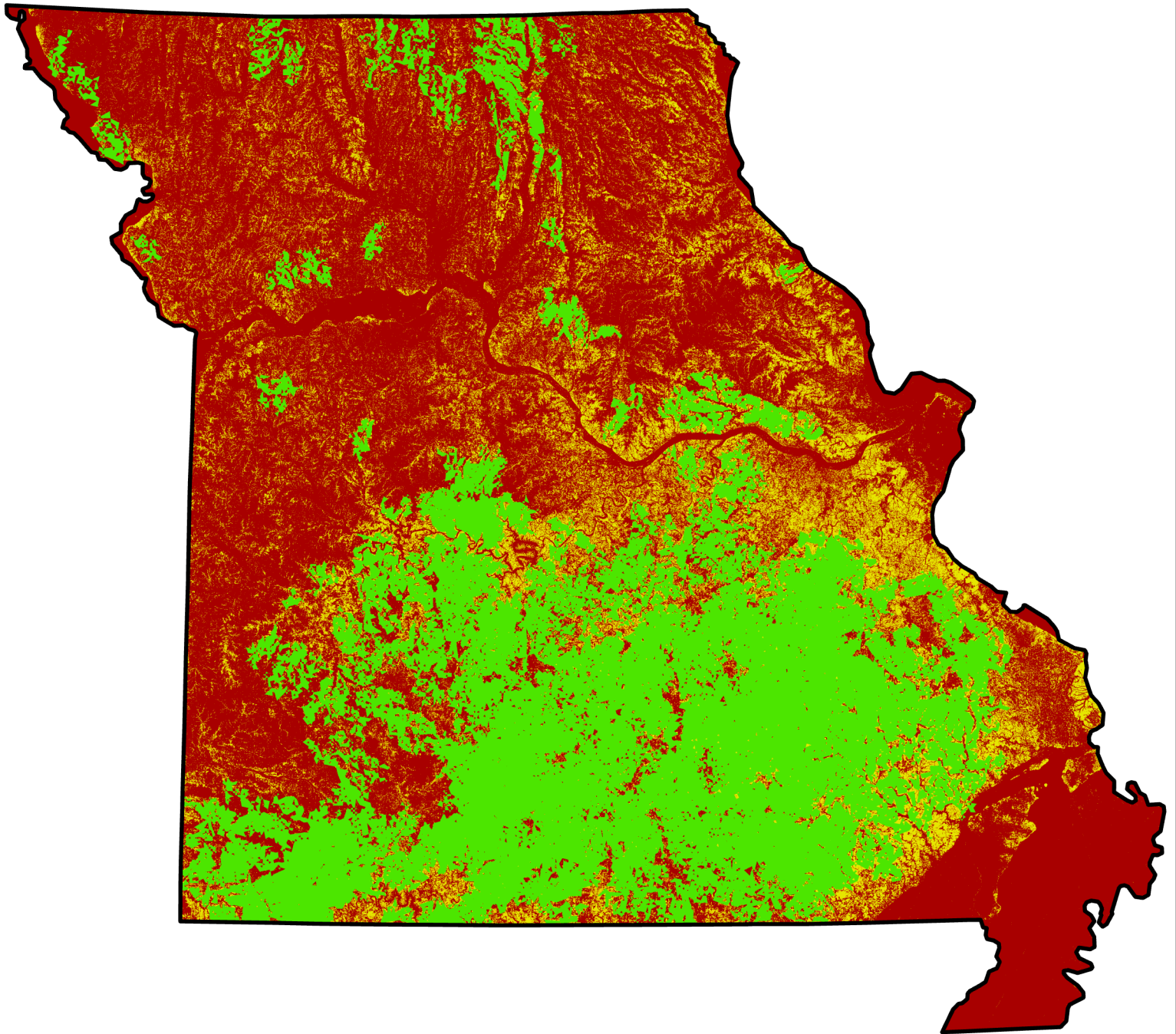


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 11: White-Tailed Deer Habitat

 Predicted Habitat  Unsuitable Habitat



0  100 mi



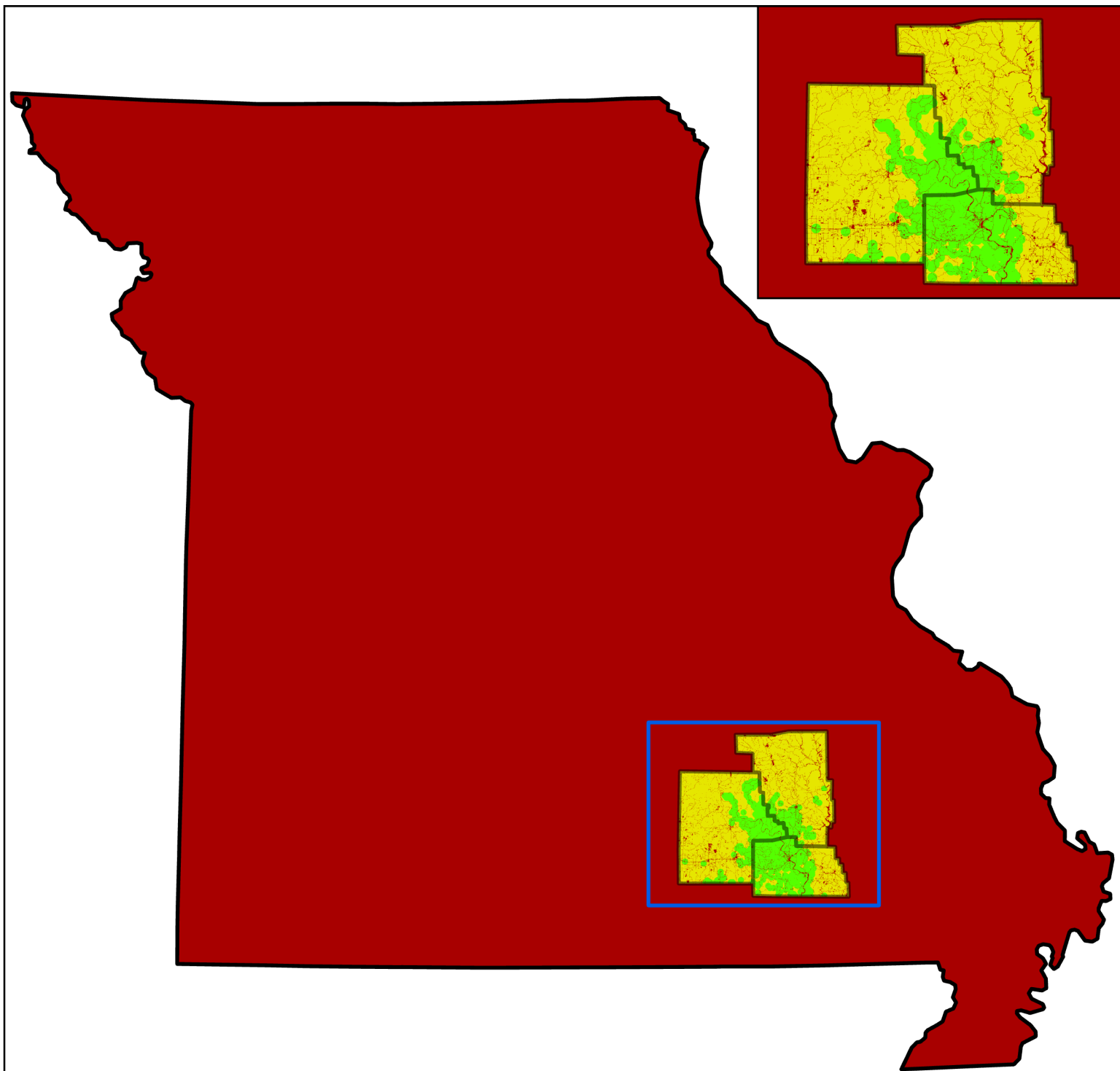
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 12: American Bear Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0

100 mi



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 13: Elk Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0

100 mi

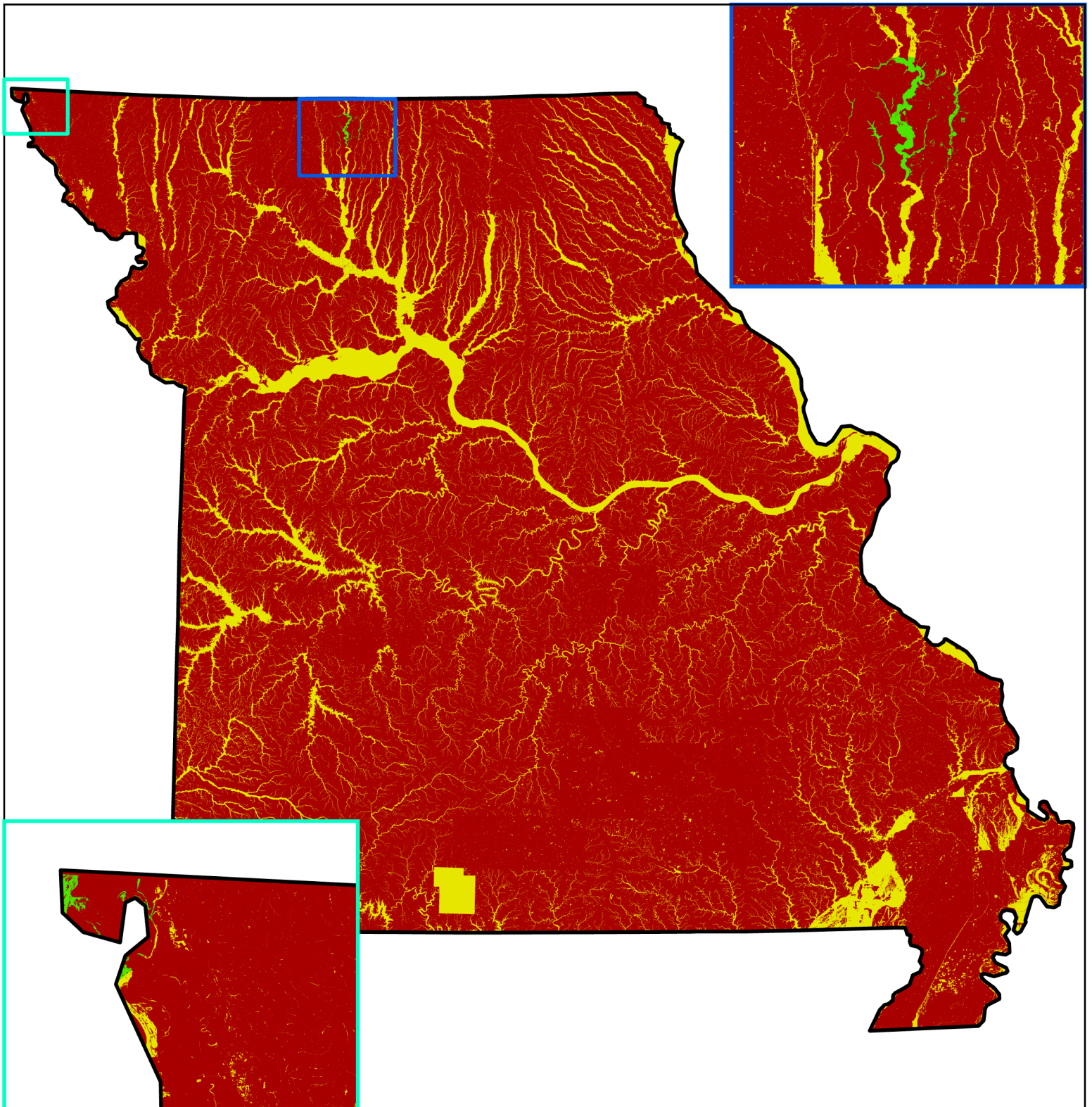


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 14: Great Plains Toad Habitat

 Occupied Habitat  Predicted Habitat  Unsuitable Habitat



0  100 mi

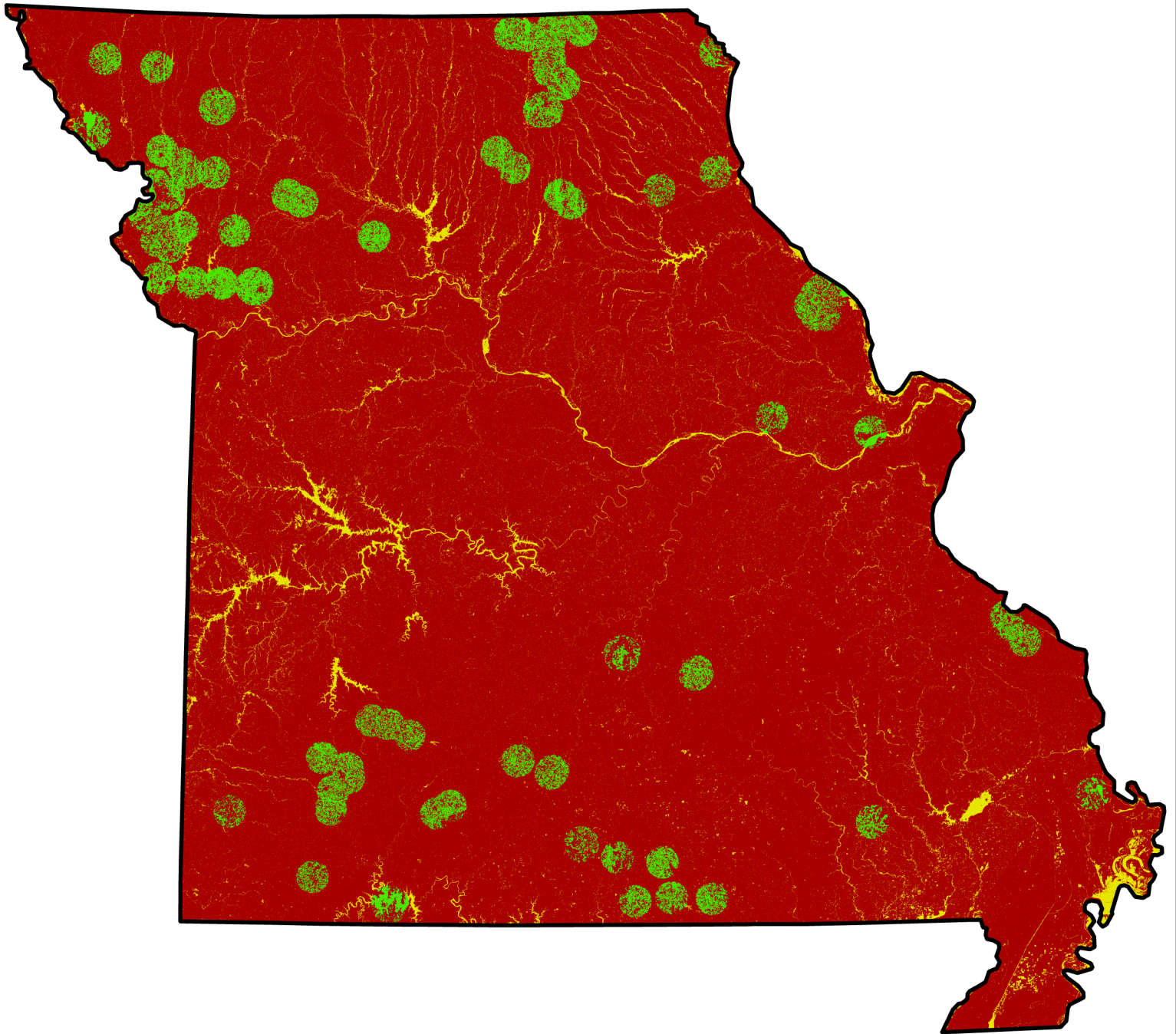


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 15: Northern Leopard Frog Habitat

 Predicted Habitat  Occupied Habitat  Unsuitable Habitat



0  100 mi

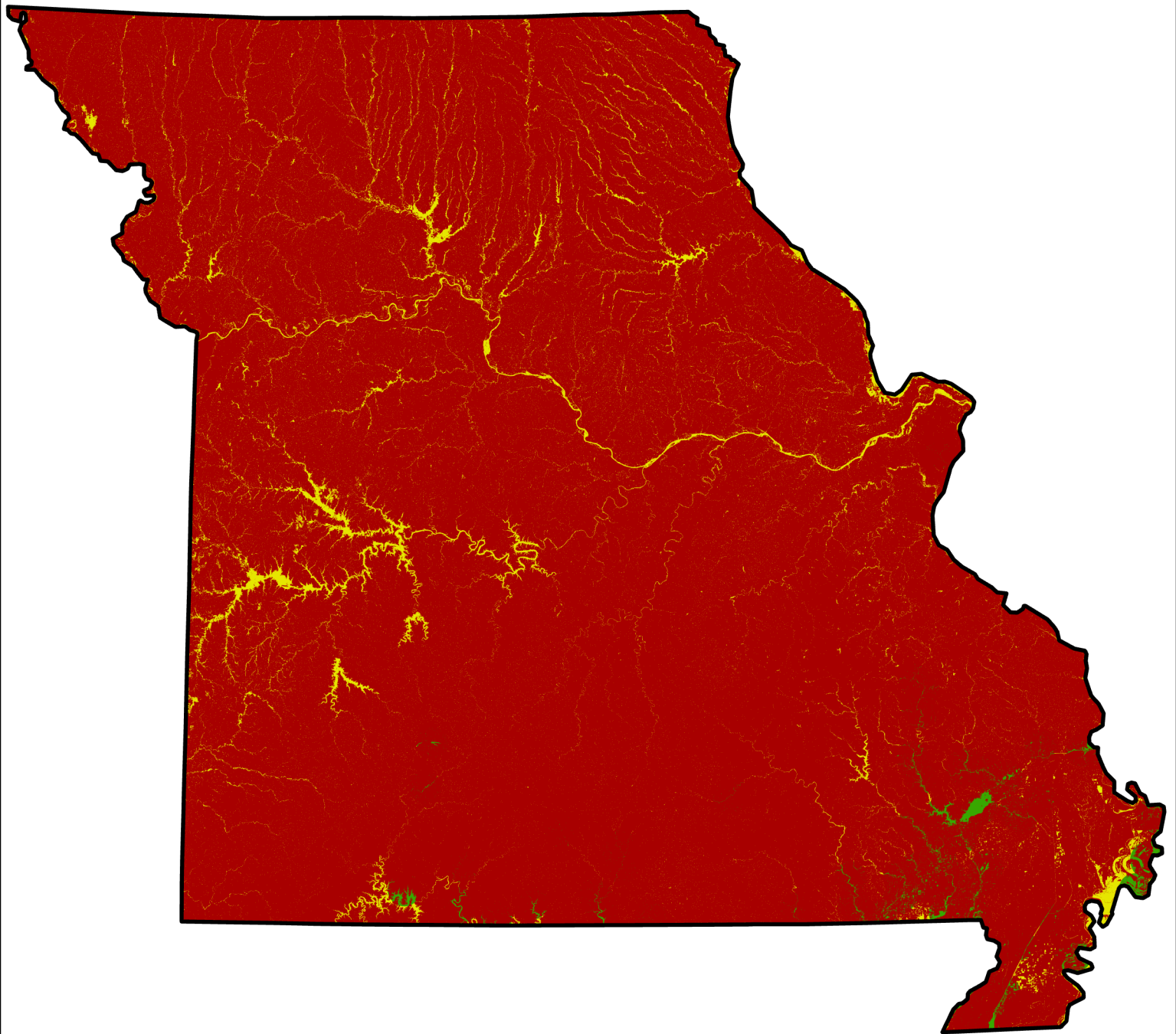


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 16: Eastern Tiger Salamander Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

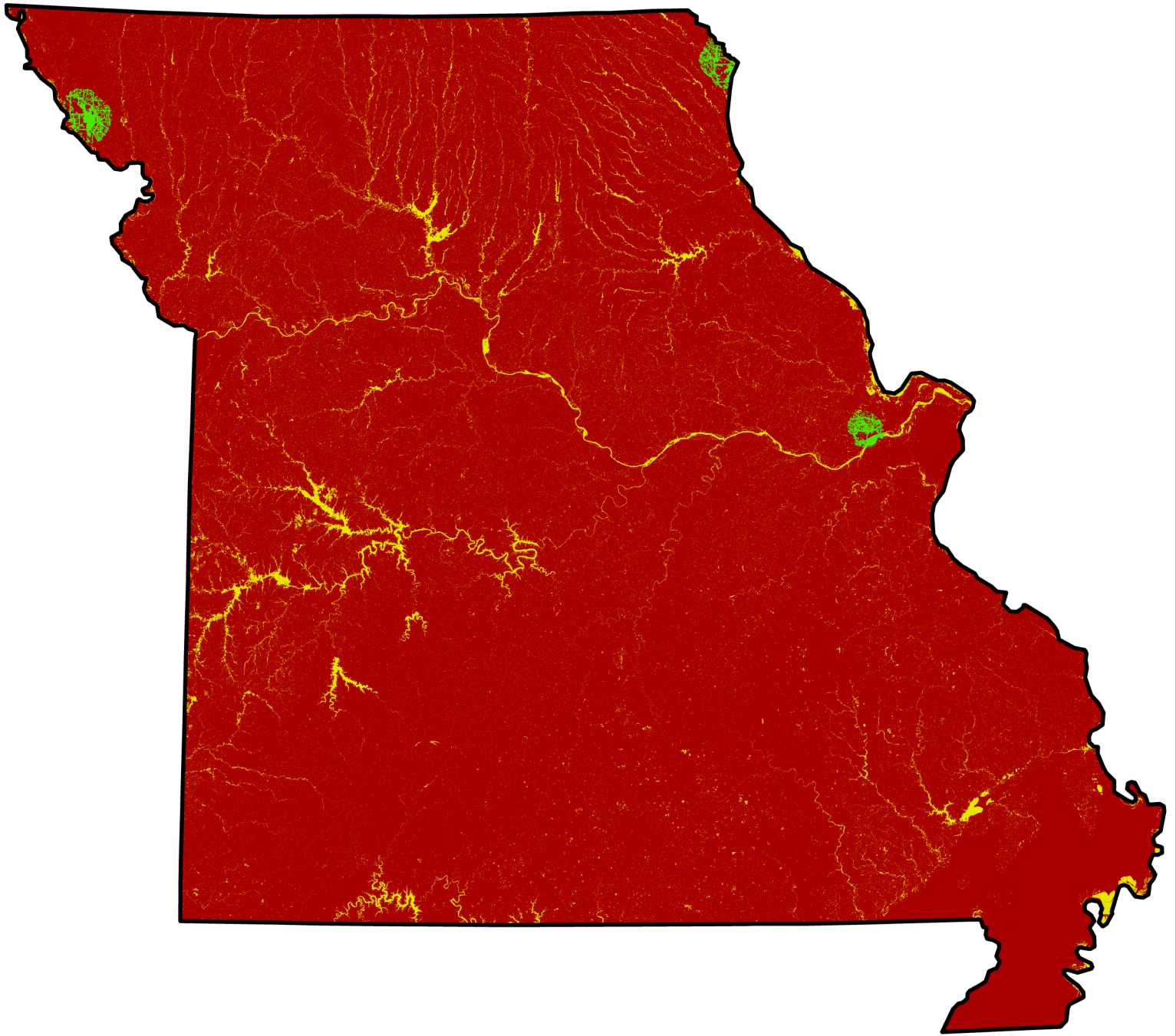


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 17: Alligator Snapping Turtle Habitat

 Occupied Habitat  Predicted Habitat  Unsuitable Habitat



0  100 mi

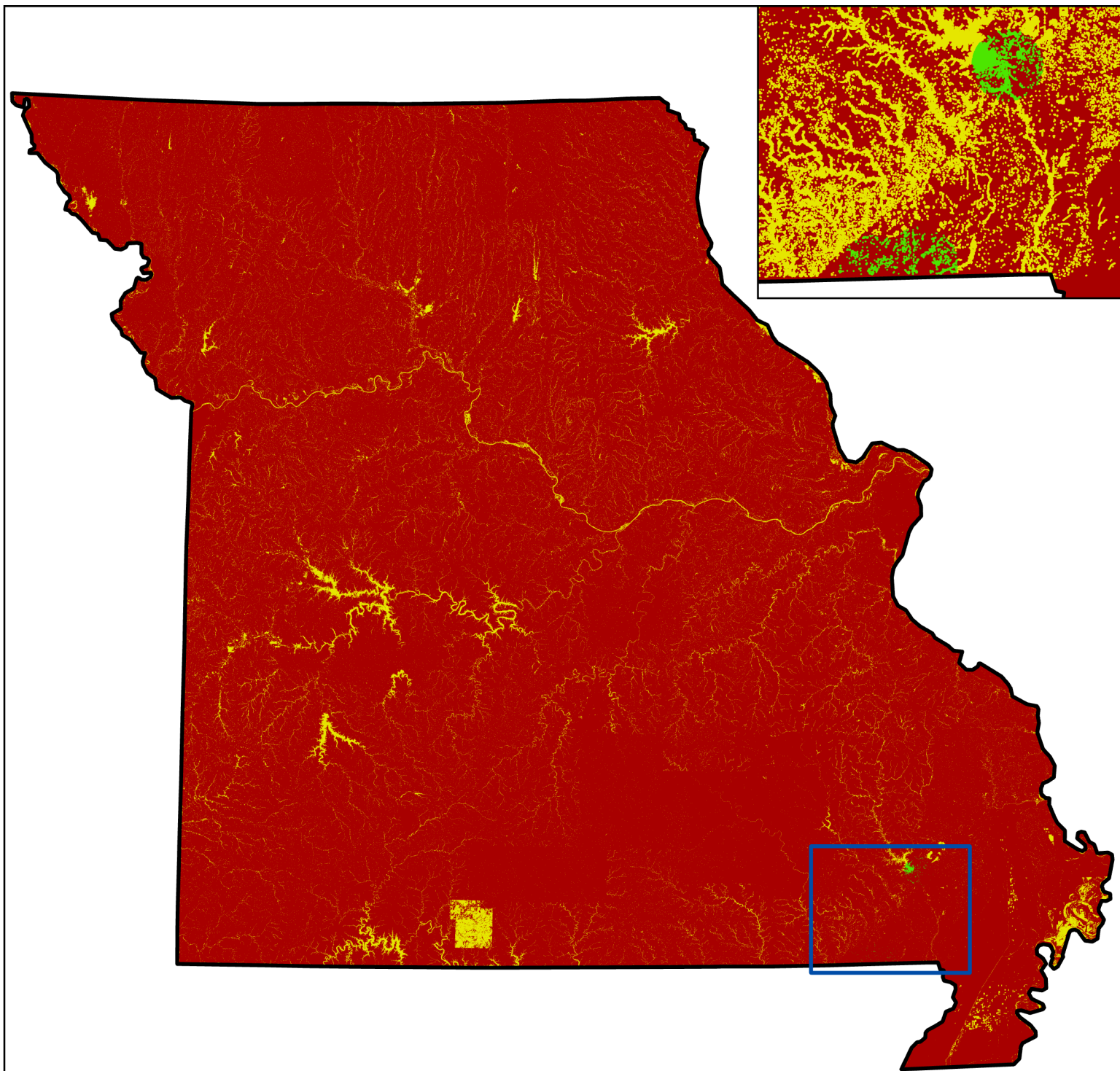


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 18: Blanding's Turtle Habitat

 Occupied Habitat  Predicted Habitat  Unsuitable Habitat



0  100 mi

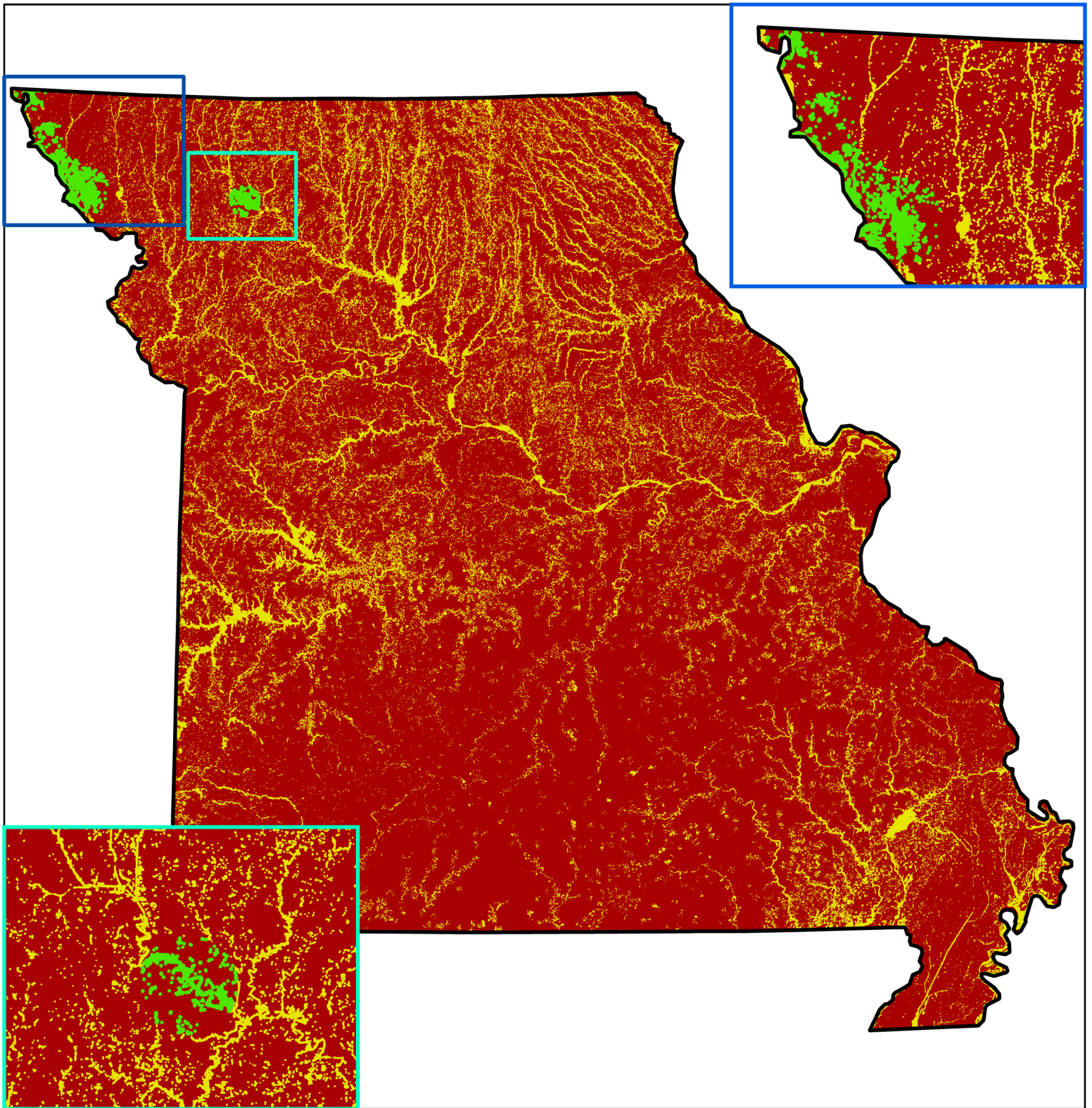


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 19: Western Chicken Turtle Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

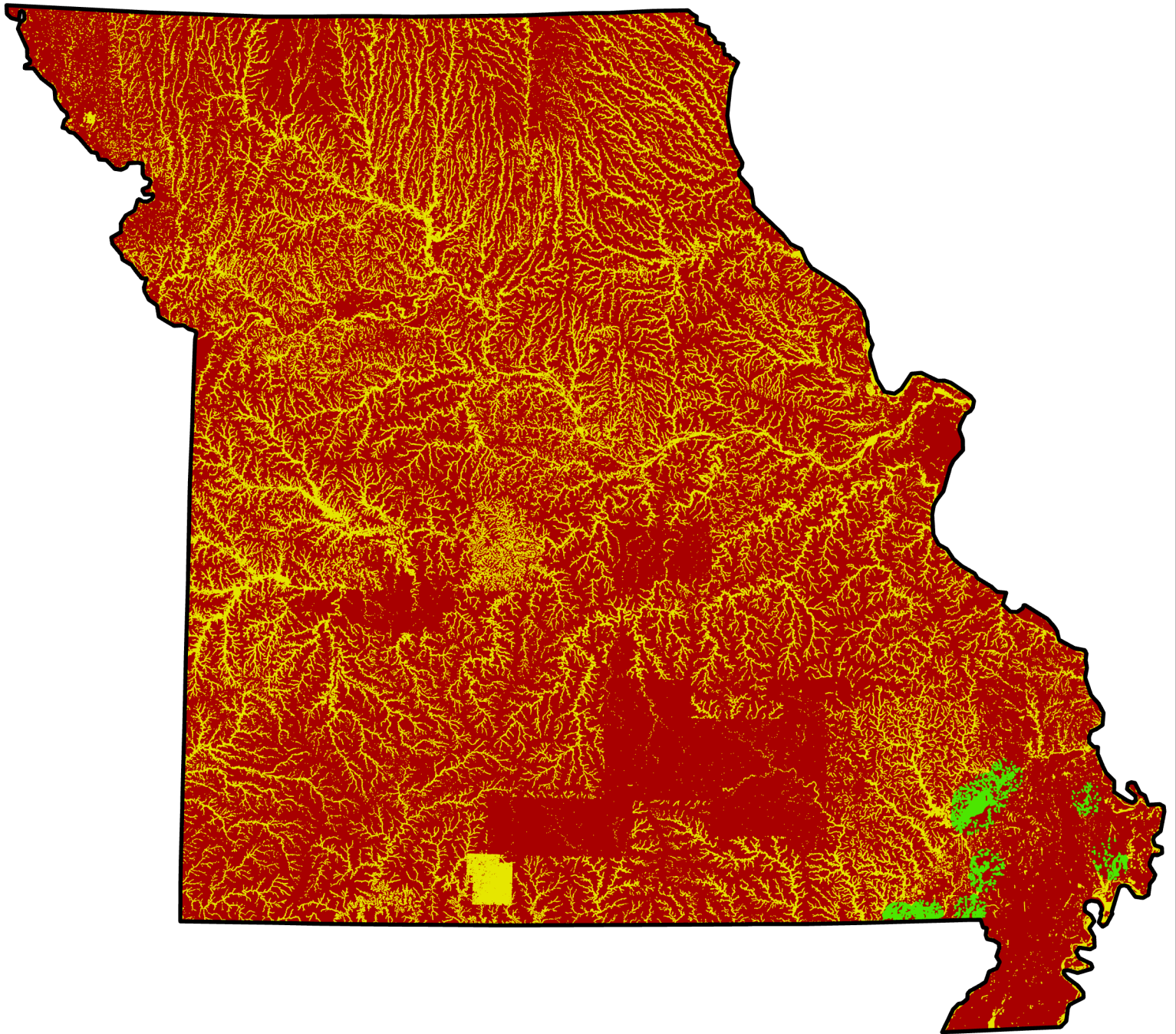


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 20: Western Foxsnake Habitat

Predicted Habitat Occupied Habitat Unsuitable Habitat



0 100 mi

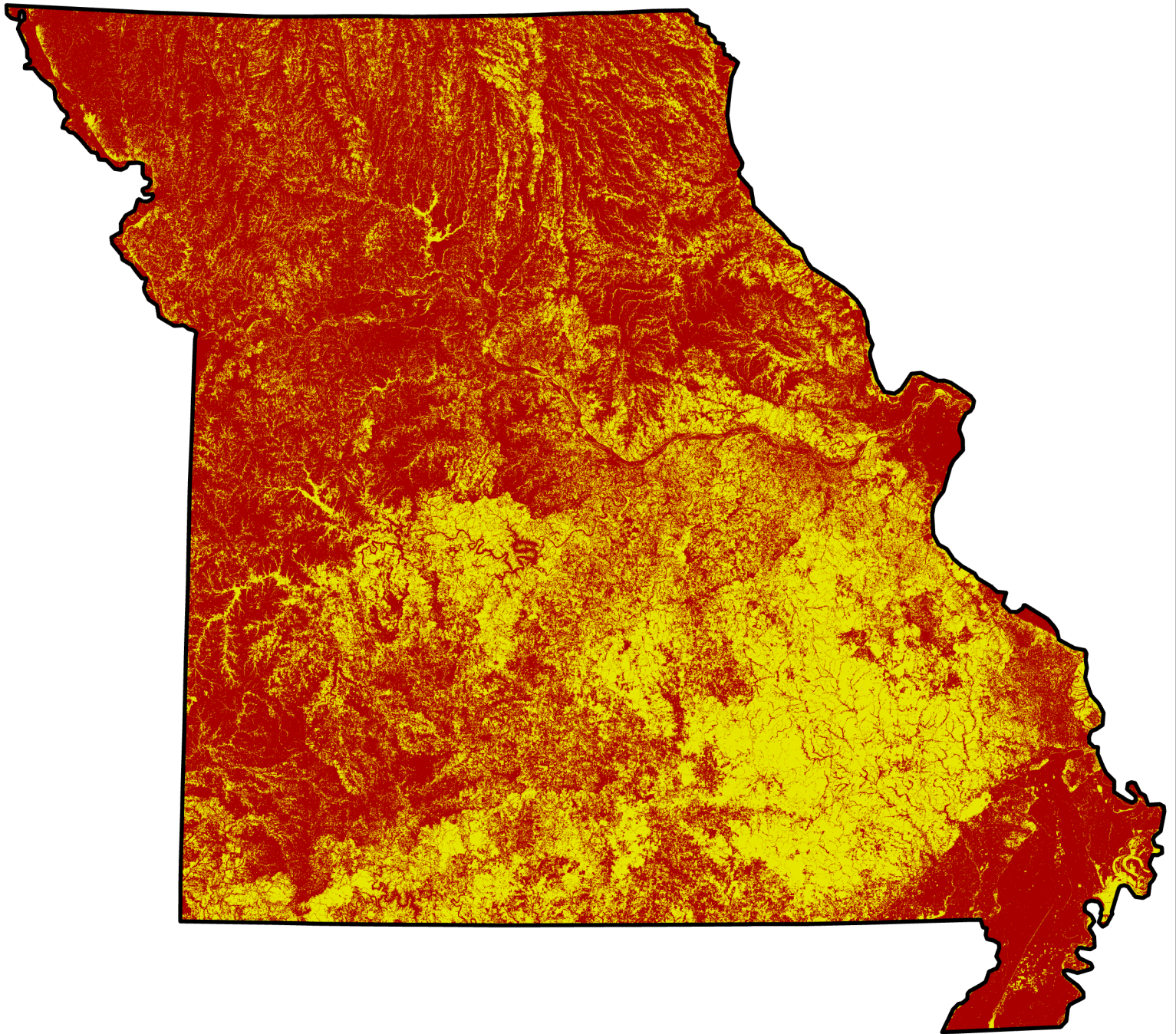


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 21: Western Mudsnae Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

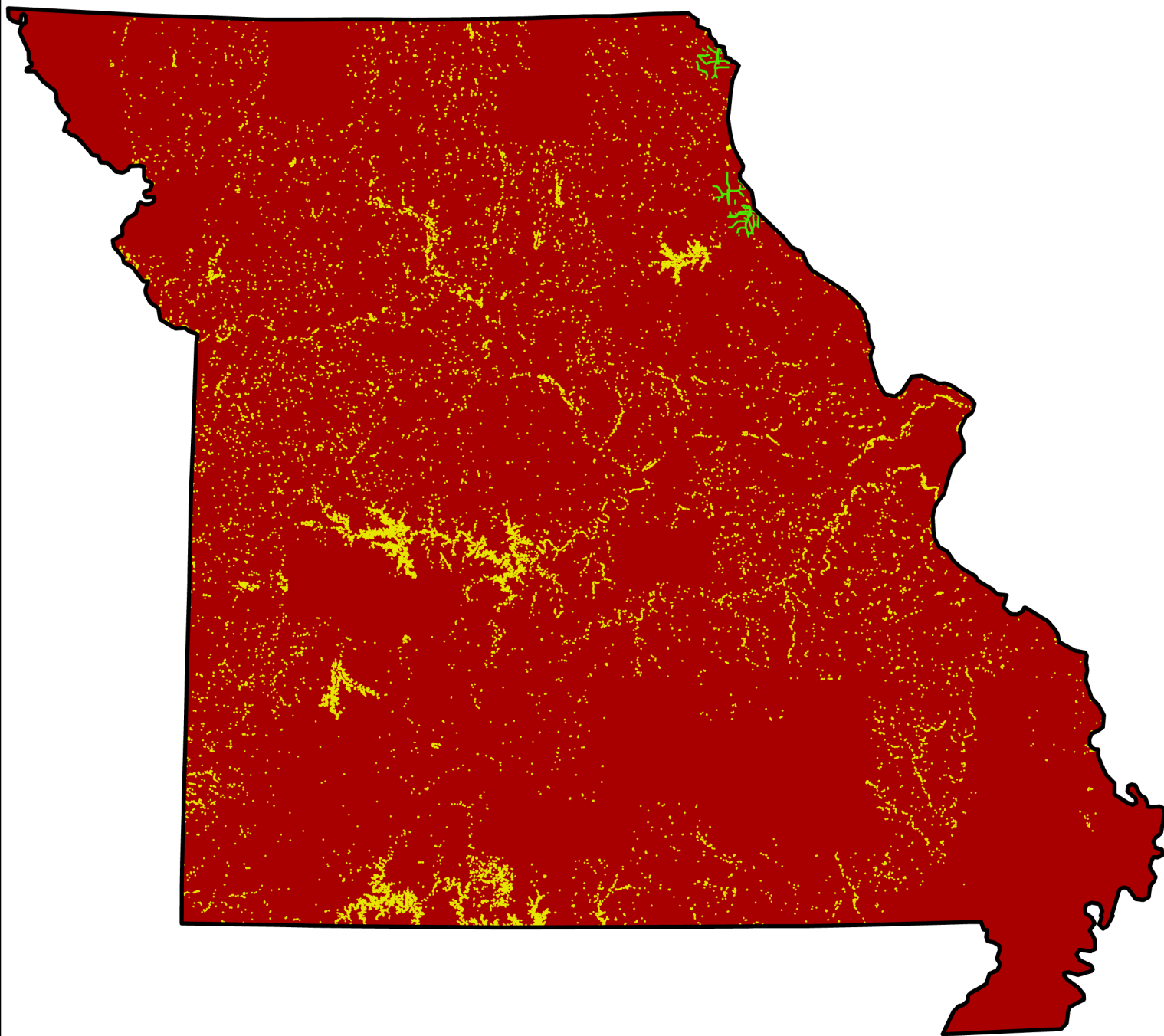


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 22: Eastern Massasauga Rattlesnake Habitat

 Predicted Habitat  Unsuitable Habitat



0  100 mi



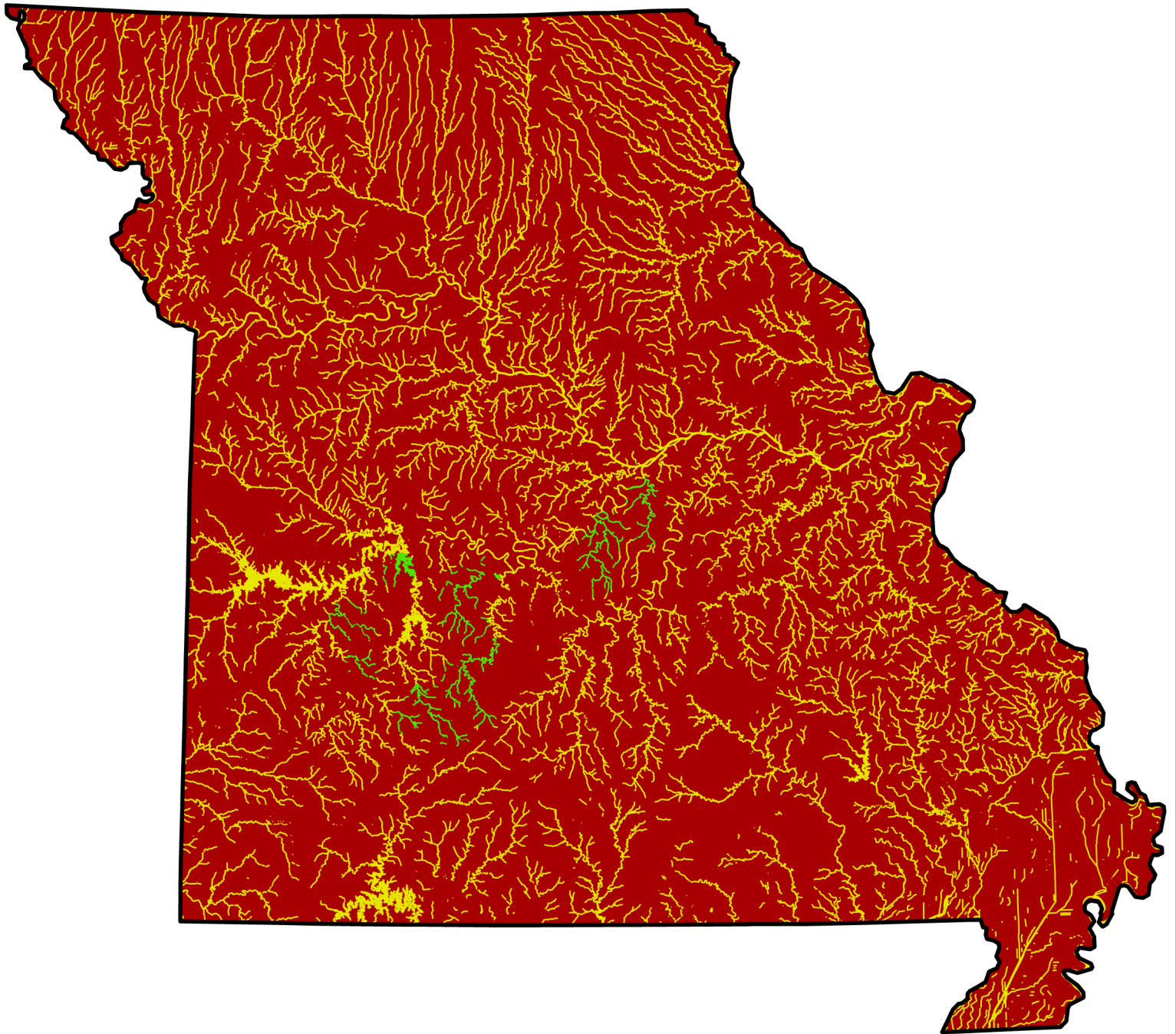
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 23 - Kirtland's Snake Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0

100 mi

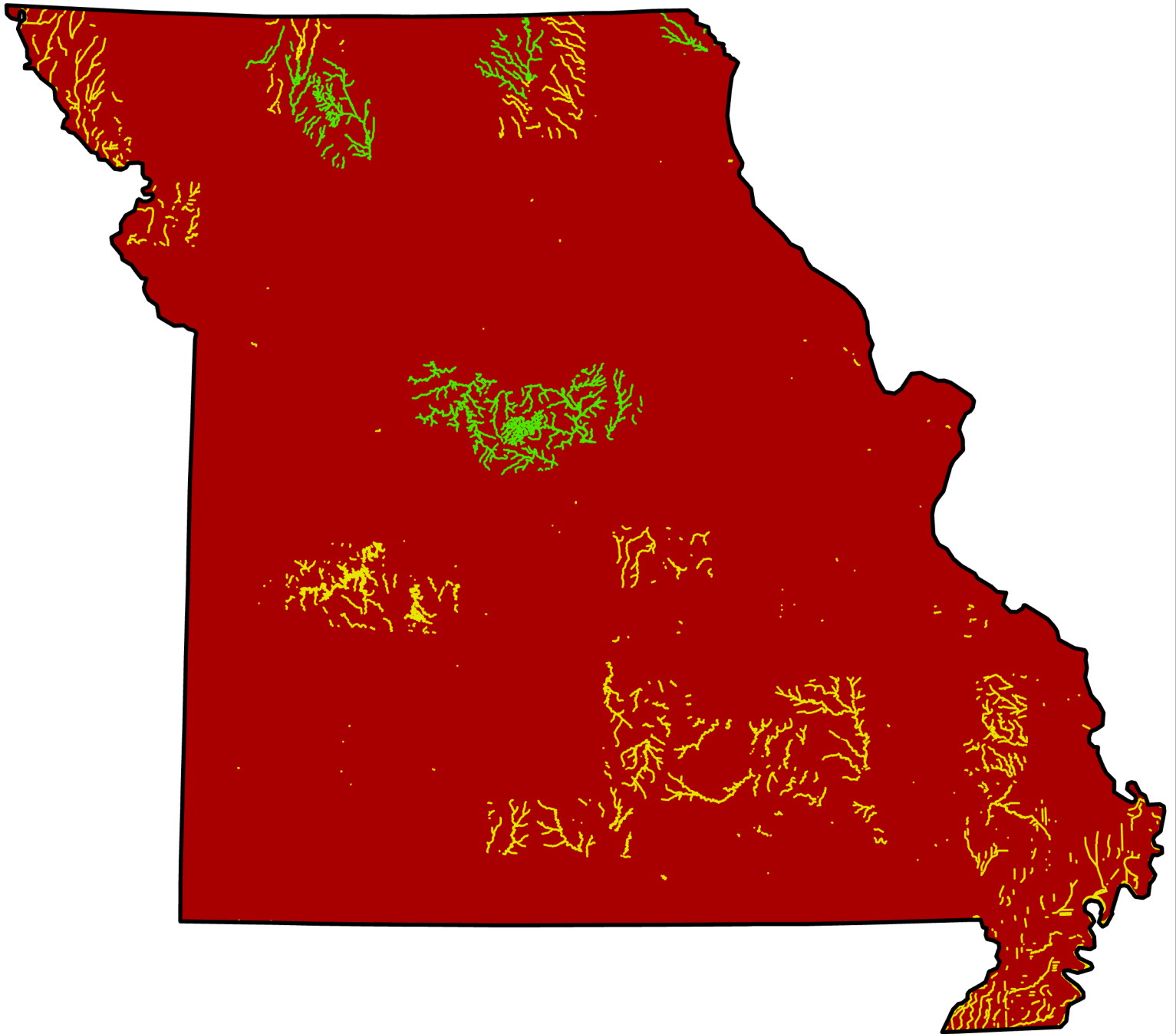


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 24: Niangua Darter Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Appendix B - Figure 25: Topeka Shiner Habitat

■ Occupied Habitat ■ Predicted Habitat ■ Unsuitable Habitat



0 100 mi

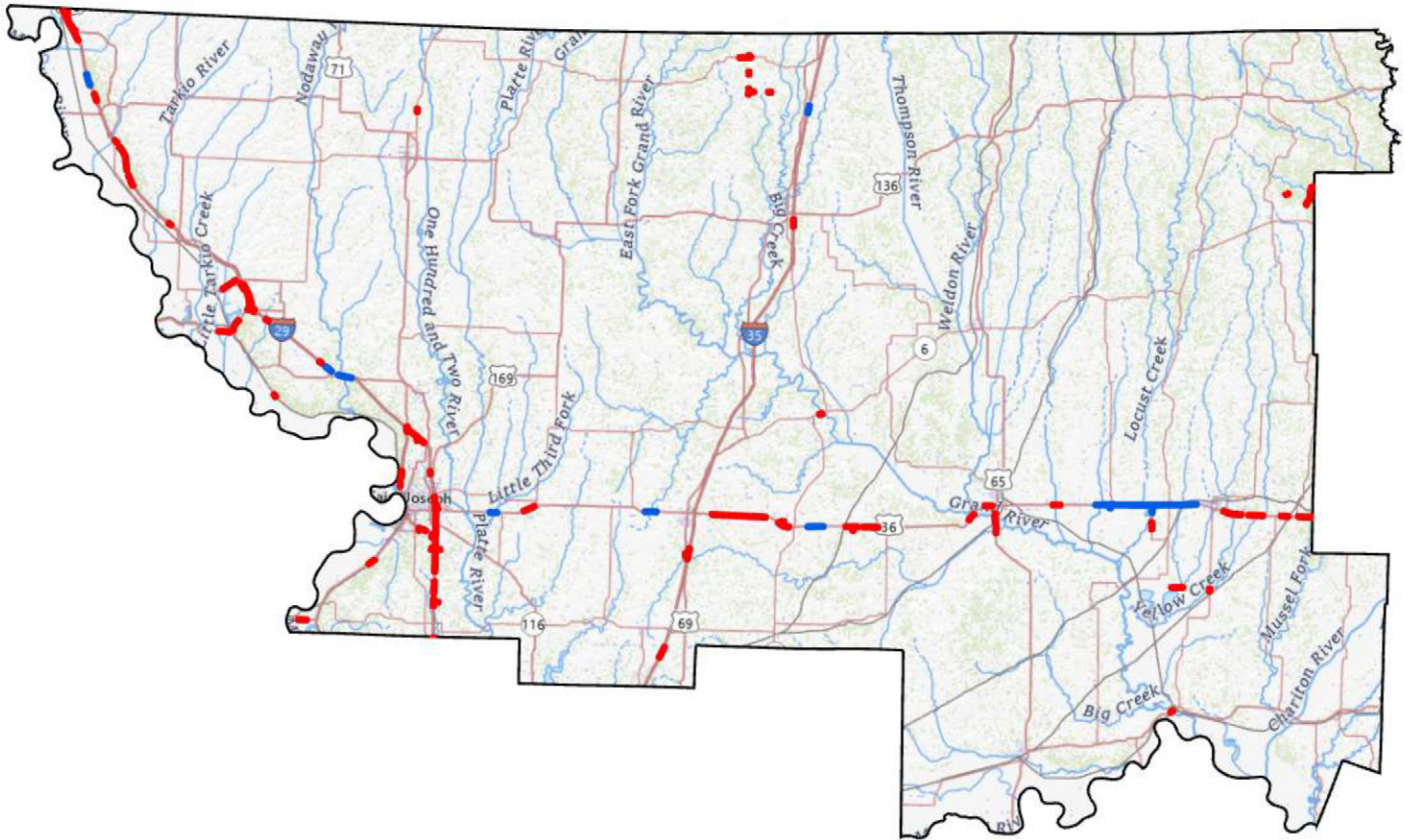


E

Priority and Top 100 Ranked
Segment Figures

Legend

- MoDOT Districts
- Priority Segments
- Top 100 Ranking Segments



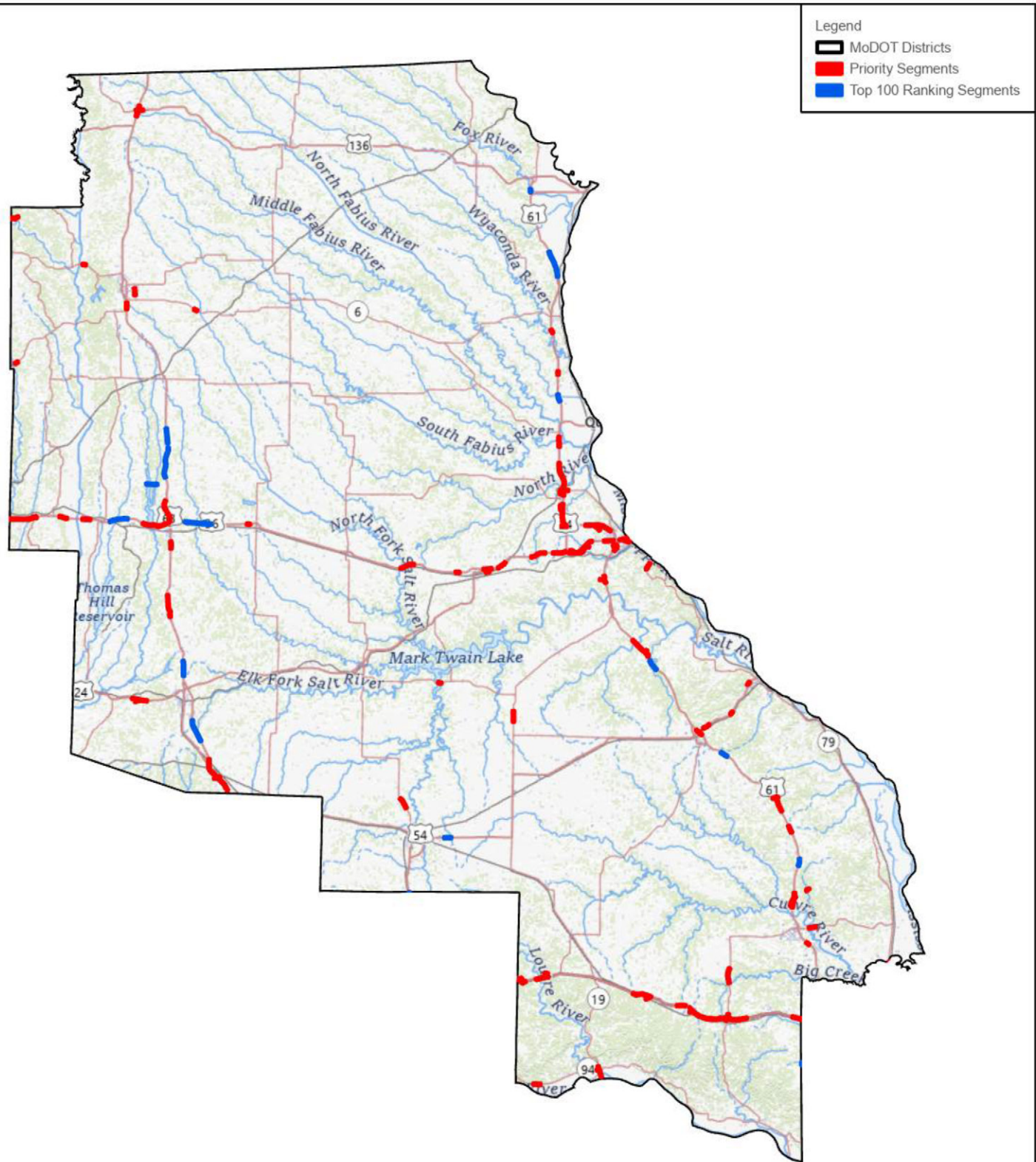
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

Priority and Top 100 Segments

NORTHWEST District



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road data; Natural Earth Data; U.S. Department of State HIU; NOAA National Centers for Environmental Information. Data refreshed February, 2025.



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

Priority and Top 100 Segments

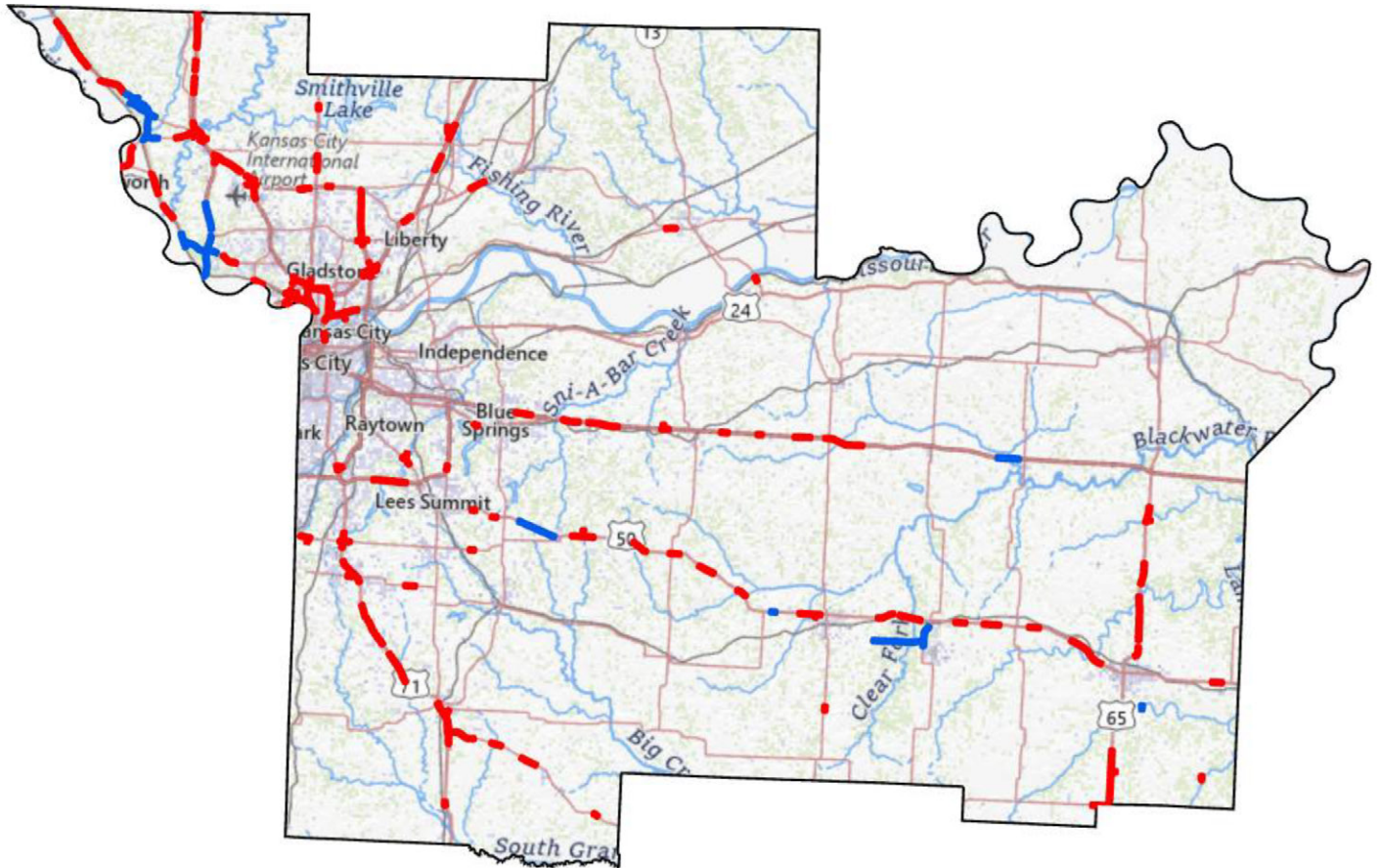
NORTHEAST District



0 40 mi

Legend

- MoDOT Districts
- Priority Segments
- Top 100 Ranking Segments



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

Priority and Top 100 Segments

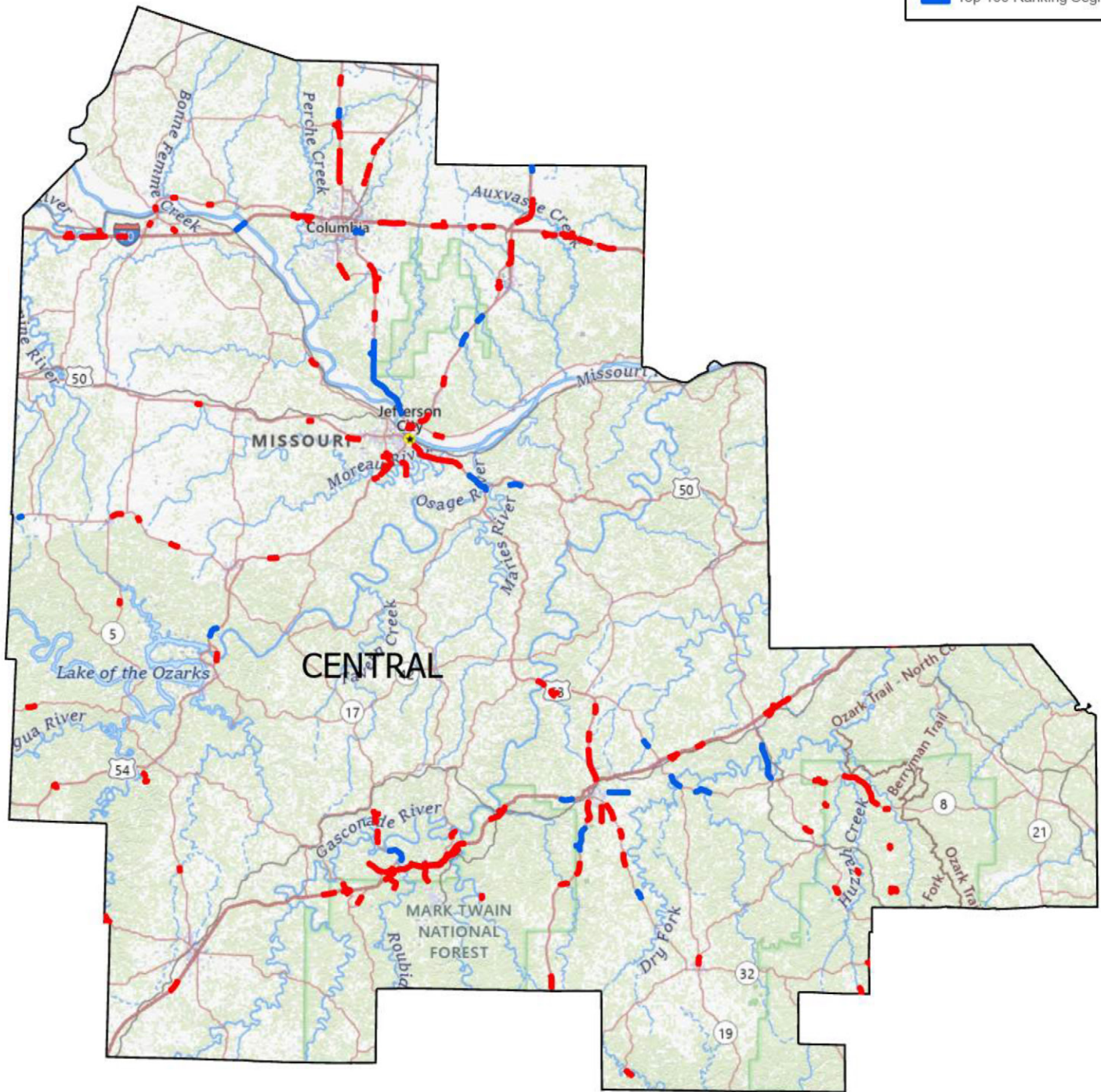
KANSAS CITY District



0 20 mi

Legend

- MoDOT Districts
- Priority Segments
- Top 100 Ranking Segments



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

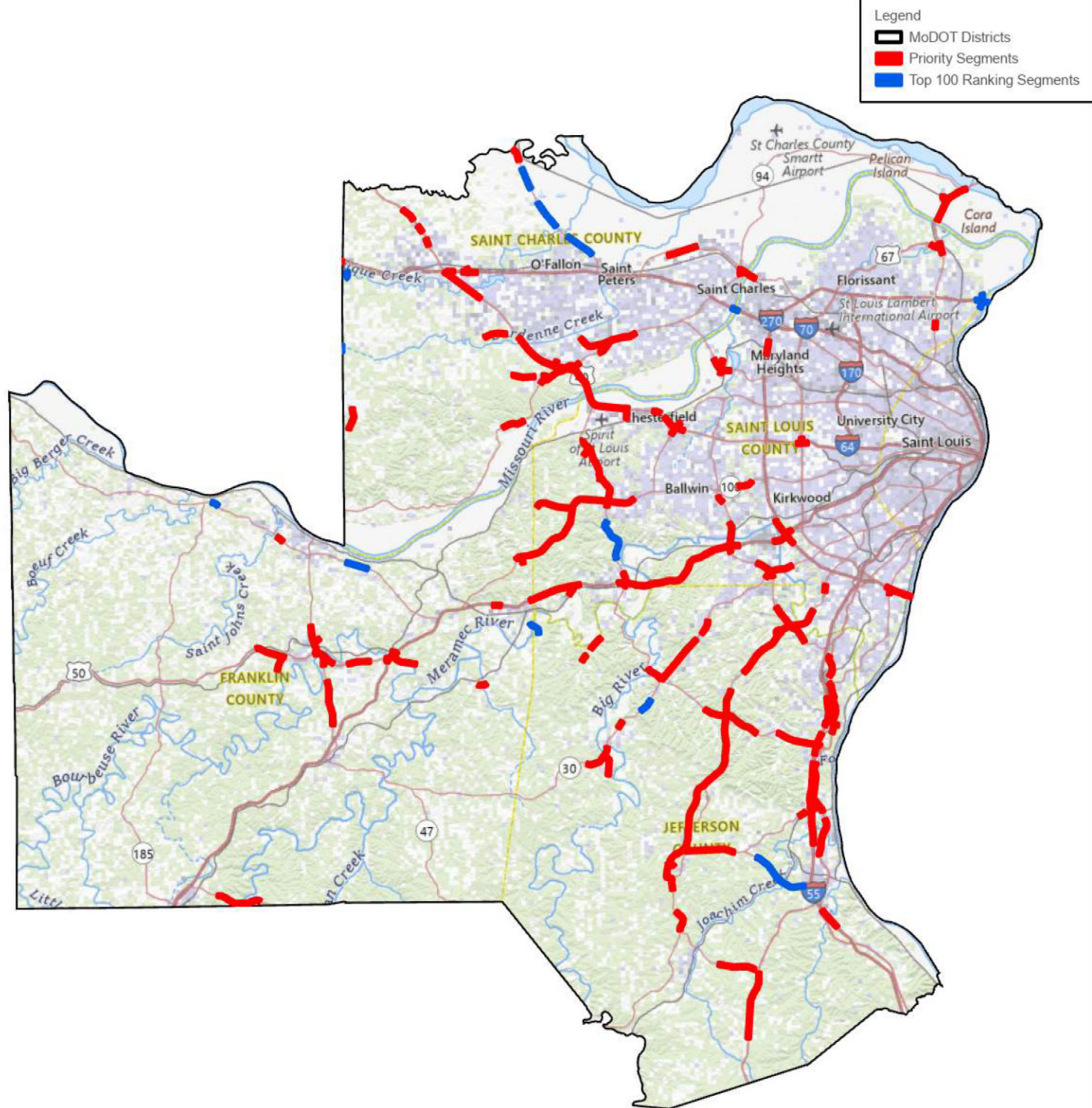
Priority and Top 100 Segments

CENTRAL District



0 40 mi

USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road data; Natural Earth Data; U.S. Department of State HIU; NOAA National Centers for Environmental Information. Data refreshed February, 2025.



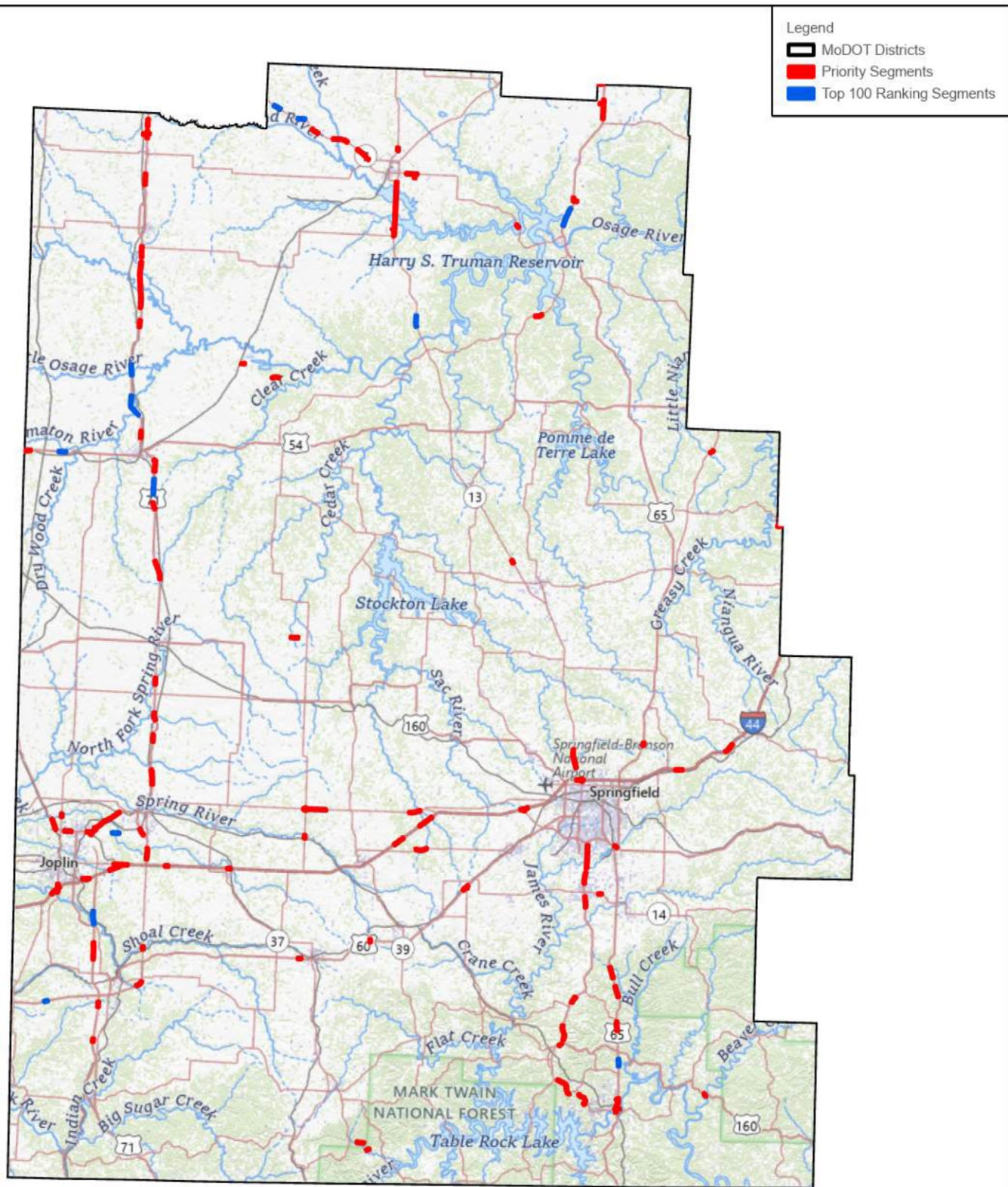
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

Priority and Top 100 Segments

ST. LOUIS District



0 20 mi



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study

Priority and Top 100 Segments

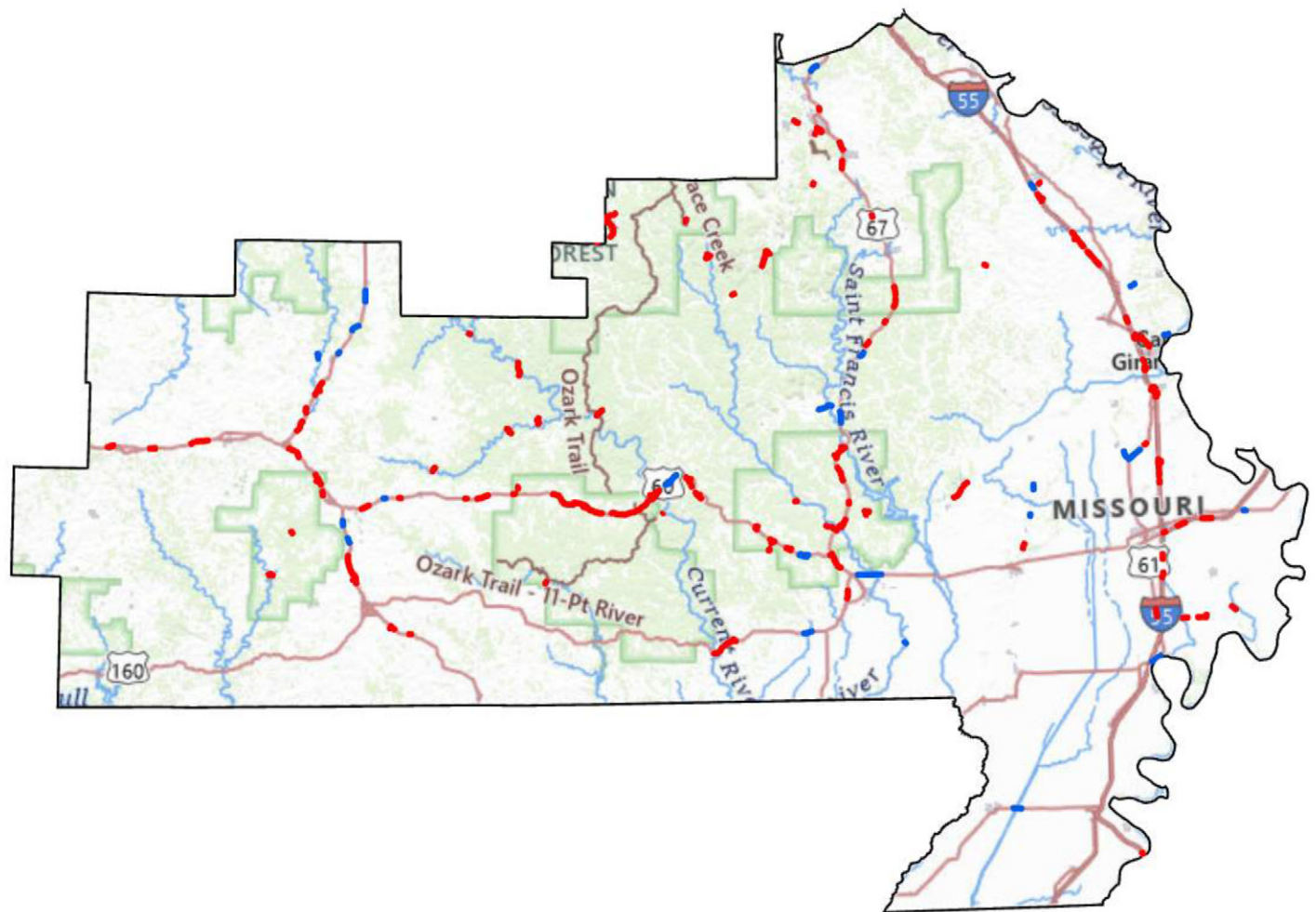
SOUTHWEST District



0 40 mi

Legend

- MoDOT Districts
- Priority Segments
- Top 100 Ranking Segments



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study
Priority and Top 100 Segments
SOUTHEAST District

0
60 mi

USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road data; Natural Earth Data; U.S. Department of State HIU; NOAA National Centers for Environmental Information. Data refreshed February, 2025.



F

Top 100 Ranked Segment Qualitative Review Table

Top 100 Priority Segment Qualitative Review

Priority Rank	Average Land Use Score	Average Constructability Score	Average STIP Score	Average Final Rank	Top 10 Segments
46	3.00	3.00	3	1	Pershing State Park
2	3.00	3.00	2	3	Four Rivers Conservation Area (1)
30	3.00	3.00	2	3	Wappapello Reservoir
54	3.00	3.00	2	3	Whiteman Airforce Base and Knob Knoster State Park
26	2.67	3.00	2	5	Four Rivers Conservation Area (2)
86	2.00	2.33	3	6.5	Parma Woods Shooting Range
53	2.33	2.00	3	6.5	Not selected due to a low safety criteria score.
29	3.00	3.00	1	8	Not selected due to a low safety criteria score and lack of protected areas.
1	2.67	2.67	1	9.5	Fox River and Buck Run (1)
4	2.33	2.00	2	9.5	Long Branch State Park
5	3.00	3.00	0	11	Meramac Springs State Park
21	3.00	1.67	1	12	Fox River and Buck Run (2)
15	3.00	2.67	0	14.5	Roubidoux Creek Conservation Area
39	3.00	2.67	0	14.5	Not selected due to low traffic volume and only two recorded crashes in 10 years.
87	3.00	2.67	0	14.5	Honey Creek Conservation Area (1)
28	2.67	3.00	0	14.5	
3	2.33	3.00	0	18	
38	1.67	1.67	2	18	
24	3.00	2.33	0	18	Honey Creek Conservation Area (2)
48	1.33	2.00	2	22	
23	2.67	2.67	0	22	
31	2.67	2.67	0	22	
91	2.67	2.67	0	22	
97	2.00	1.33	2	22	
6	2.67	2.33	0	27	
64	2.33	2.67	0	27	
82	2.33	2.67	0	27	
100	2.67	2.33	0	27	
99	3.00	2.00	0	27	
13	2.33	2.33	0	33.5	

Top 100 Priority Segment Qualitative Review

Priority Rank	Average Land Use Score	Average Constructability Score	Average STIP Score	Average Final Rank	Top 10 Segments
17	2.33	2.33	0	33.5	
18	2.33	2.33	0	33.5	
43	2.33	2.33	0	33.5	
58	2.33	2.33	0	33.5	
61	2.33	2.33	0	33.5	
49	2.00	1.67	1	33.5	
73	3.00	1.67	0	33.5	
8	0.67	1.00	3	38	
11	1.67	1.67	1	42.5	
80	2.00	2.33	0	42.5	
62	2.00	2.33	0	42.5	
57	2.33	1.00	1	42.5	
12	2.33	2.00	0	42.5	
35	2.33	2.00	0	42.5	
83	2.33	1.00	1	42.5	
25	2.00	2.33	0	42.5	
89	1.33	1.00	2	50	
47	2.67	1.67	0	50	
56	2.67	1.67	0	50	
95	2.67	1.67	0	50	
16	3.00	1.33	0	50	
93	1.33	2.00	1	50	
98	1.33	1.00	2	50	
88	2.00	2.00	0	58.5	
10	2.67	1.33	0	58.5	
22	2.33	1.67	0	58.5	
44	1.67	2.33	0	58.5	
55	2.67	1.33	0	58.5	
76	1.67	2.33	0	58.5	
77	2.33	1.67	0	58.5	
92	1.33	1.67	1	58.5	
79	2.00	2.00	0	58.5	
81	2.00	1.00	1	58.5	
52	2.00	1.67	0	65	
63	2.00	1.67	0	65	
75	1.33	2.33	0	65	
7	3.00	0.67	0	67	
37	2.33	1.00	0	69	
34	2.33	1.00	0	69	

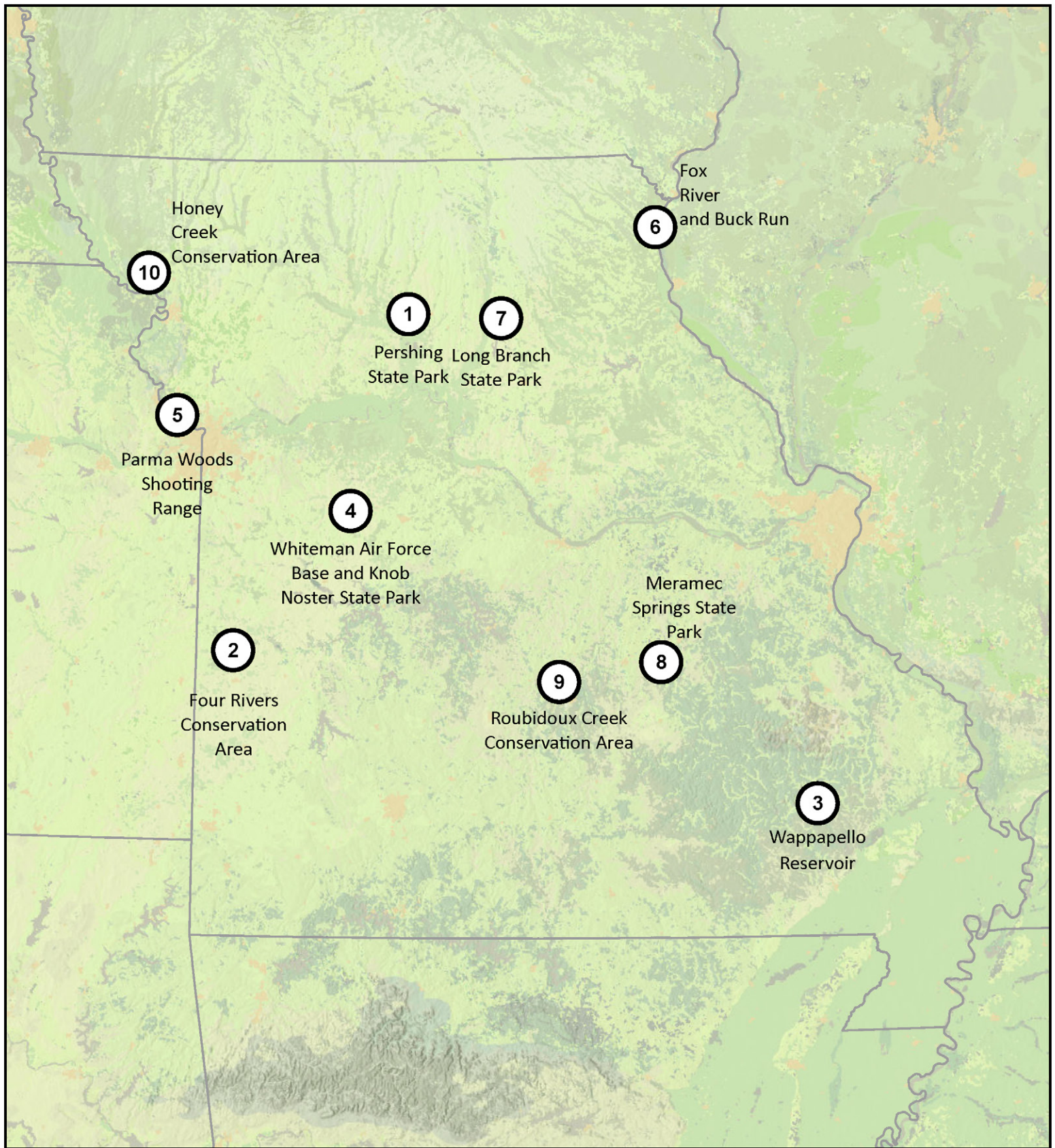
Top 100 Priority Segment Qualitative Review

Priority Rank	Average Land Use Score	Average Constructability Score	Average STIP Score	Average Final Rank	Top 10 Segments
70	2.33	1.00	0	69	
72	2.67	0.67	0	72	
94	2.67	0.67	0	72	
40	1.33	2.00	0	72	
14	2.00	1.00	0	79	
9	1.67	1.33	0	79	
20	2.33	0.67	0	79	
27	1.33	1.67	0	79	
33	2.33	0.67	0	79	
36	2.33	0.67	0	79	
41	1.67	1.33	0	79	
42	1.67	1.33	0	79	
71	1.67	1.33	0	79	
84	2.33	0.67	0	79	
32	2.00	1.00	0	79	
66	1.67	1.00	0	86	
85	1.67	1.00	0	86	
90	1.67	1.00	0	86	
51	1.33	1.33	0	88	
60	0.33	2.00	0	89.5	
78	1.67	0.67	0	89.5	
74	1.00	1.33	0	92.5	
65	1.33	1.00	0	92.5	
45	1.33	1.00	0	92.5	
69	1.33	1.00	0	92.5	
59	1.33	0.67	0	95.5	
19	1.00	1.00	0	95.5	
67	0.33	0.33	1	98	
96	1.00	0.67	0	98	
68	0.67	1.00	0	98	
50	0.33	0.67	0	100	



G

Top 10 Priority Segment Figures

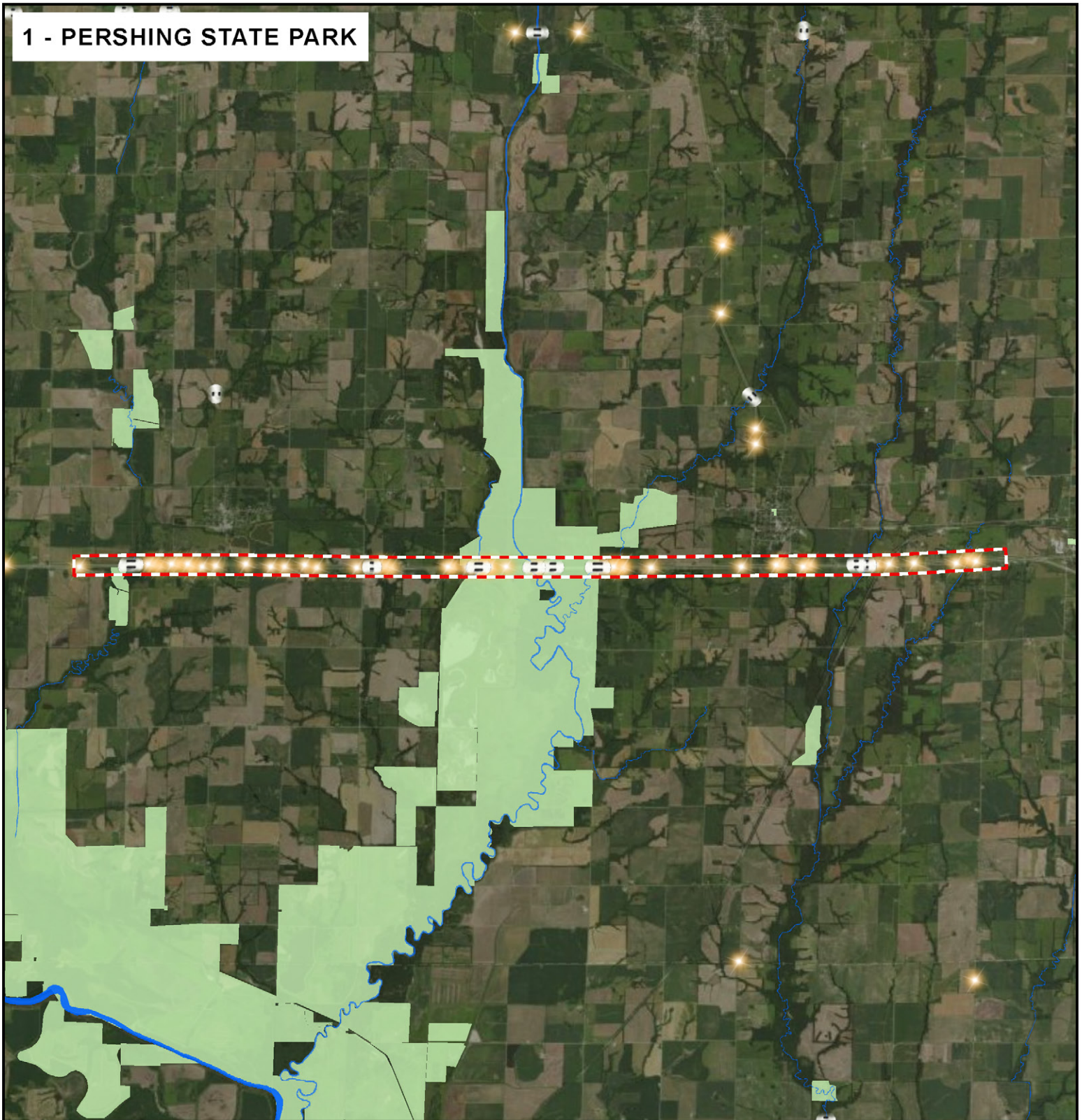


Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures



0 100 mi

1 - PERSHING STATE PARK



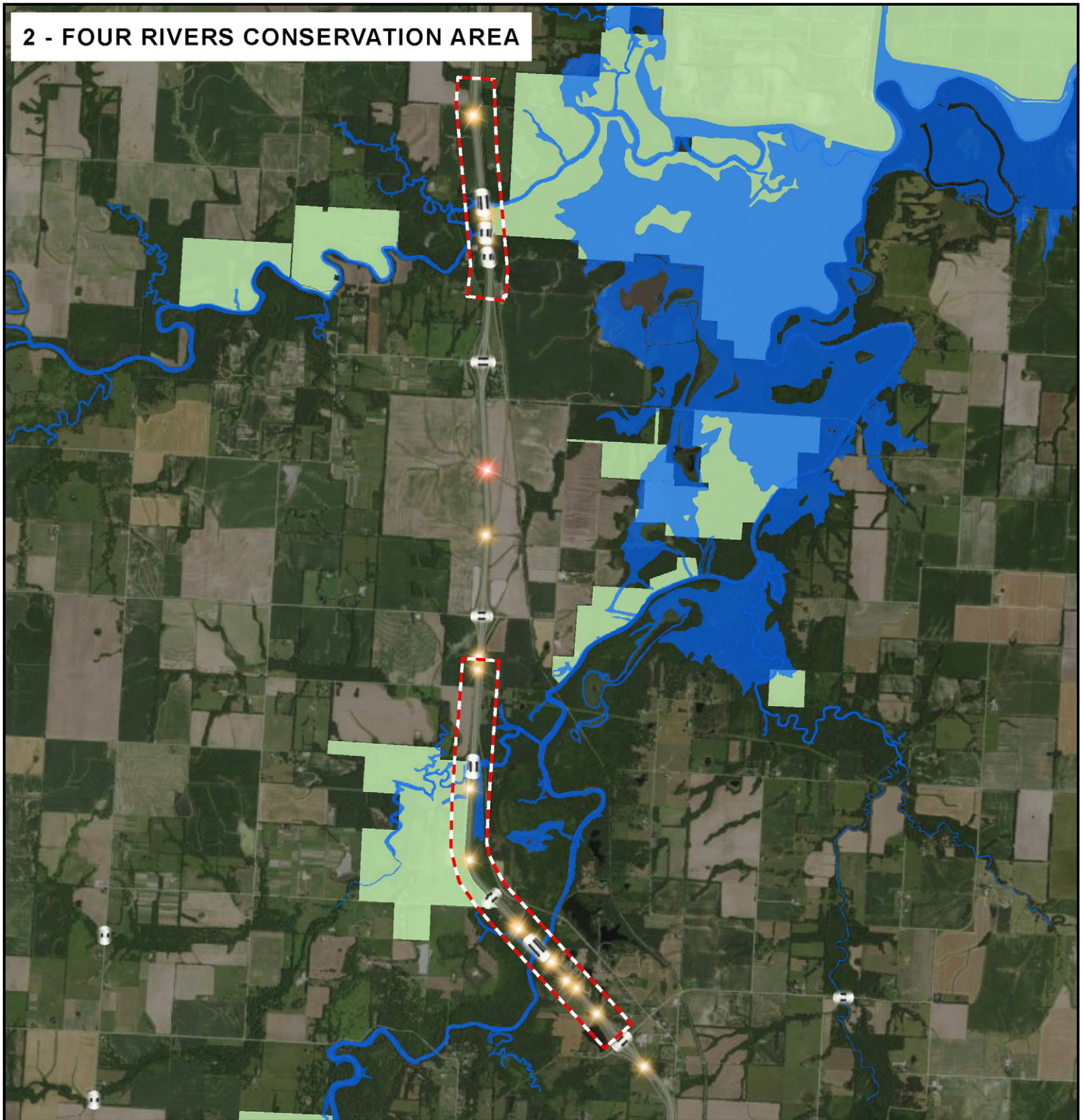
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 4 mi

2 - FOUR RIVERS CONSERVATION AREA



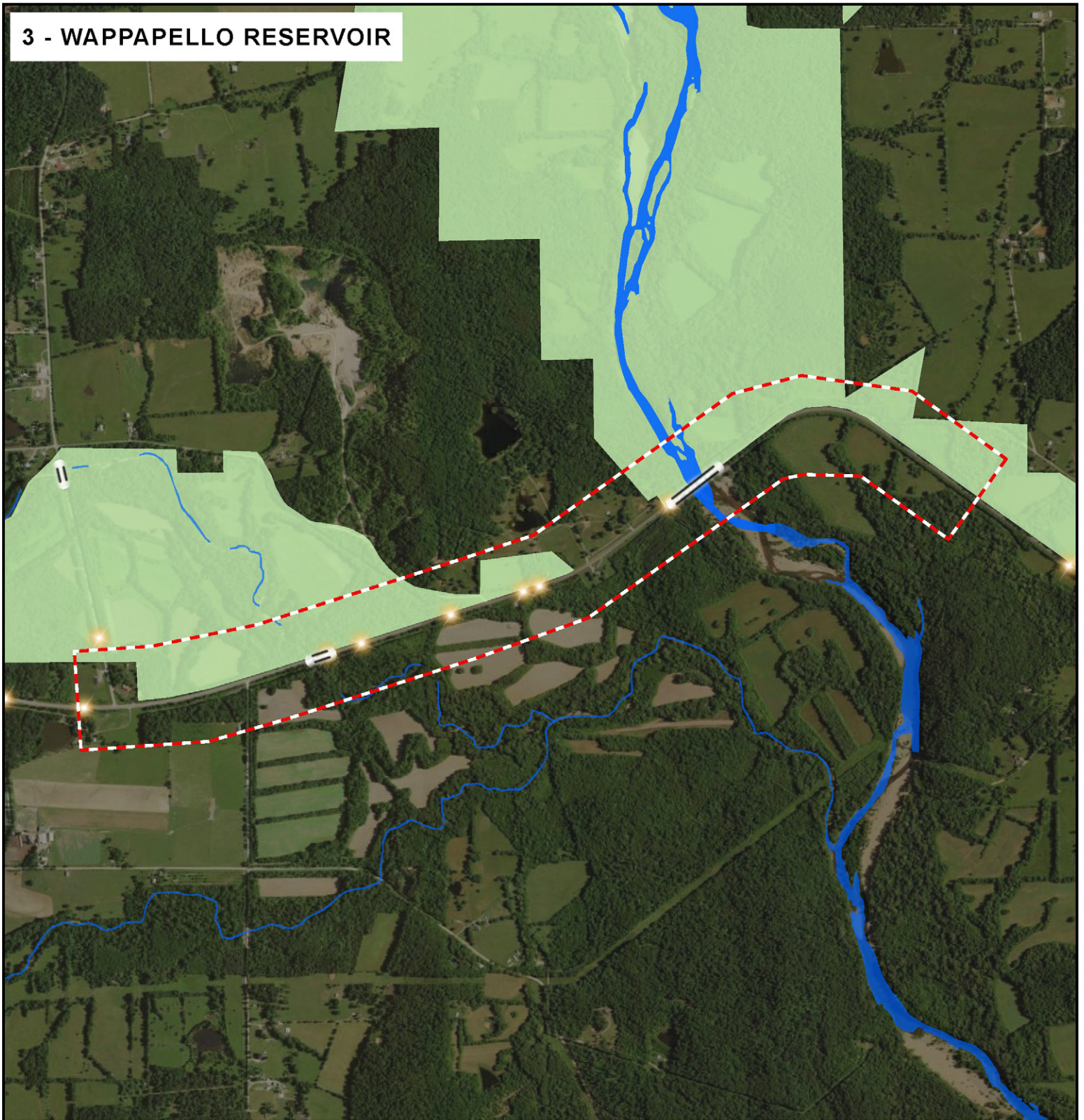
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 2 mi

3 - WAPPAPELLO RESERVOIR



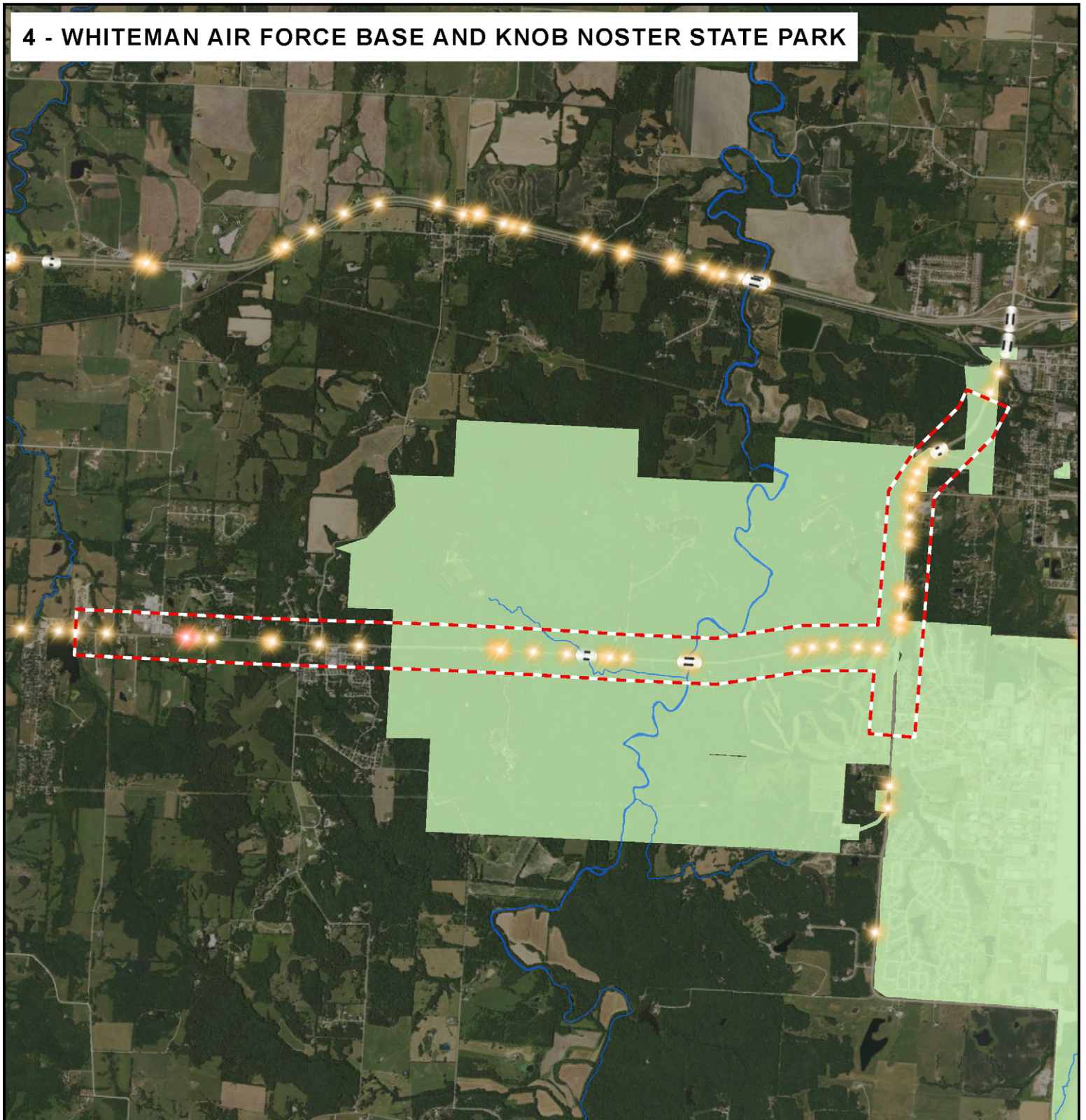
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 0.7 mi

4 - WHITEMAN AIR FORCE BASE AND KNOB NOSTER STATE PARK



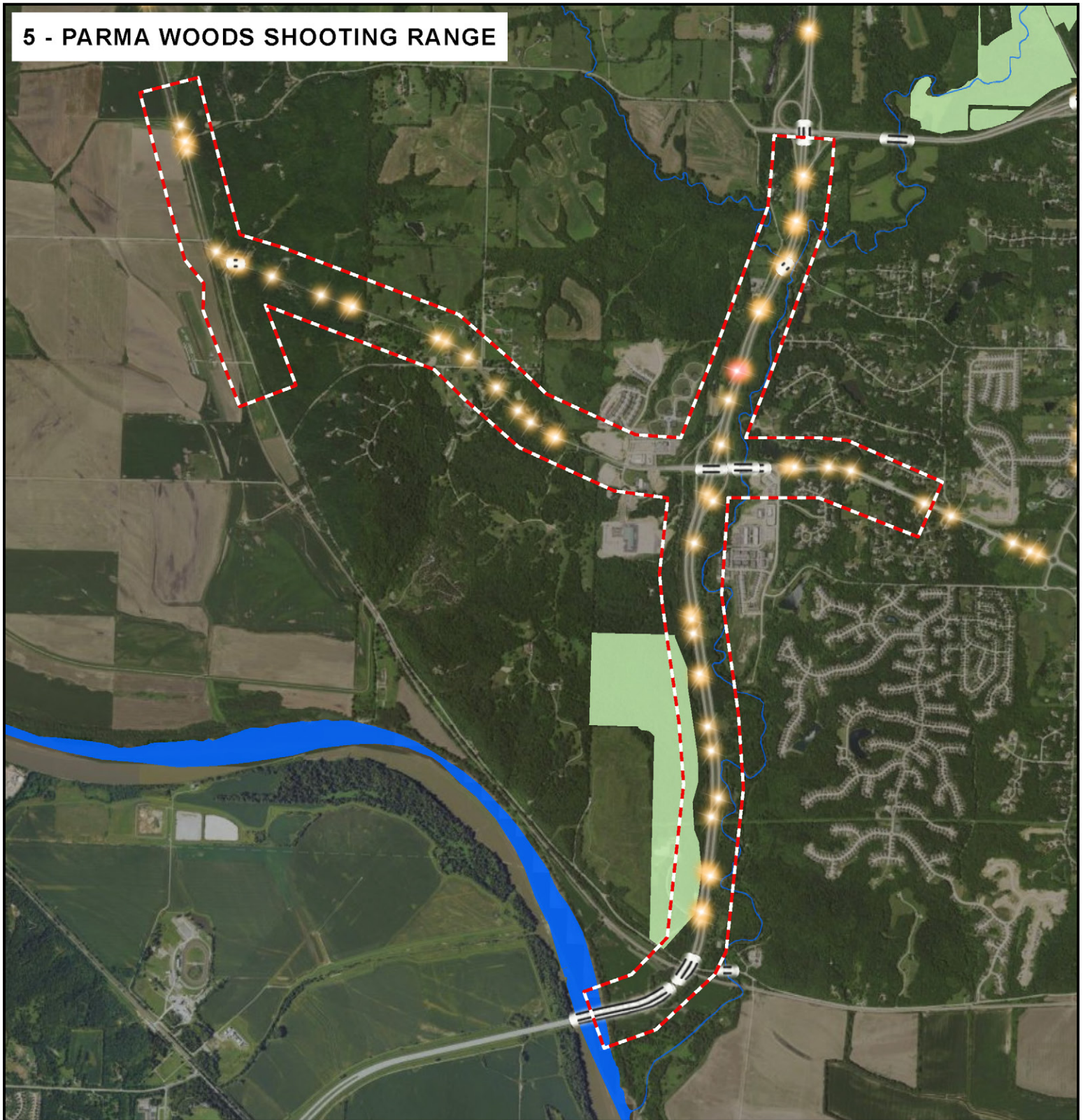
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 1.7 mi

5 - PARMA WOODS SHOOTING RANGE



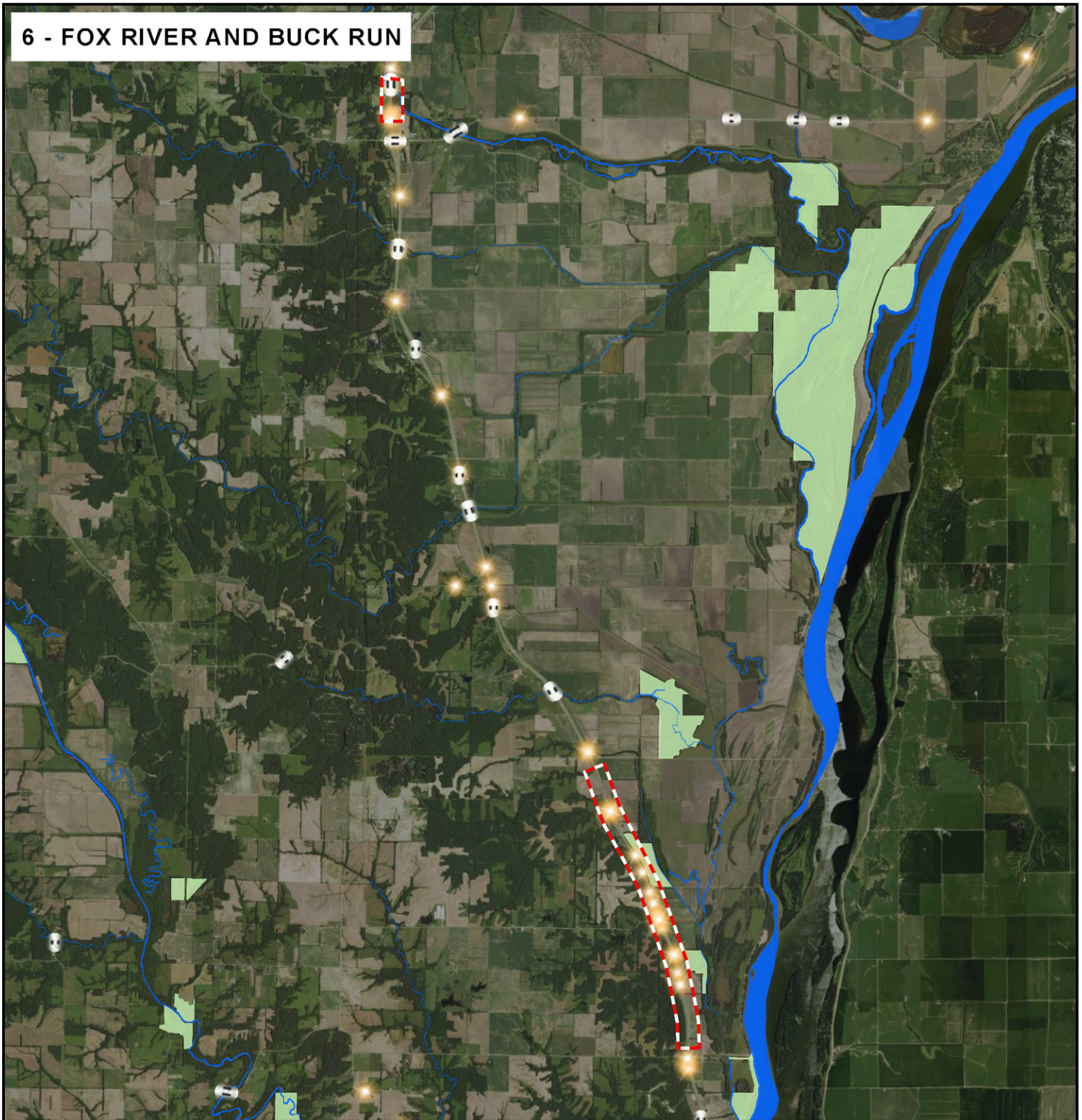
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- - - Top 10 Hot Spots
- Stream (NHD)
- ★ Fatal Wildlife Crashes 2019 to 2023
- ★ Wildlife Crashes 2019 to 2023
- Protected Areas
- = MoDOT Bridges & Culverts



0 1.2 mi

6 - FOX RIVER AND BUCK RUN



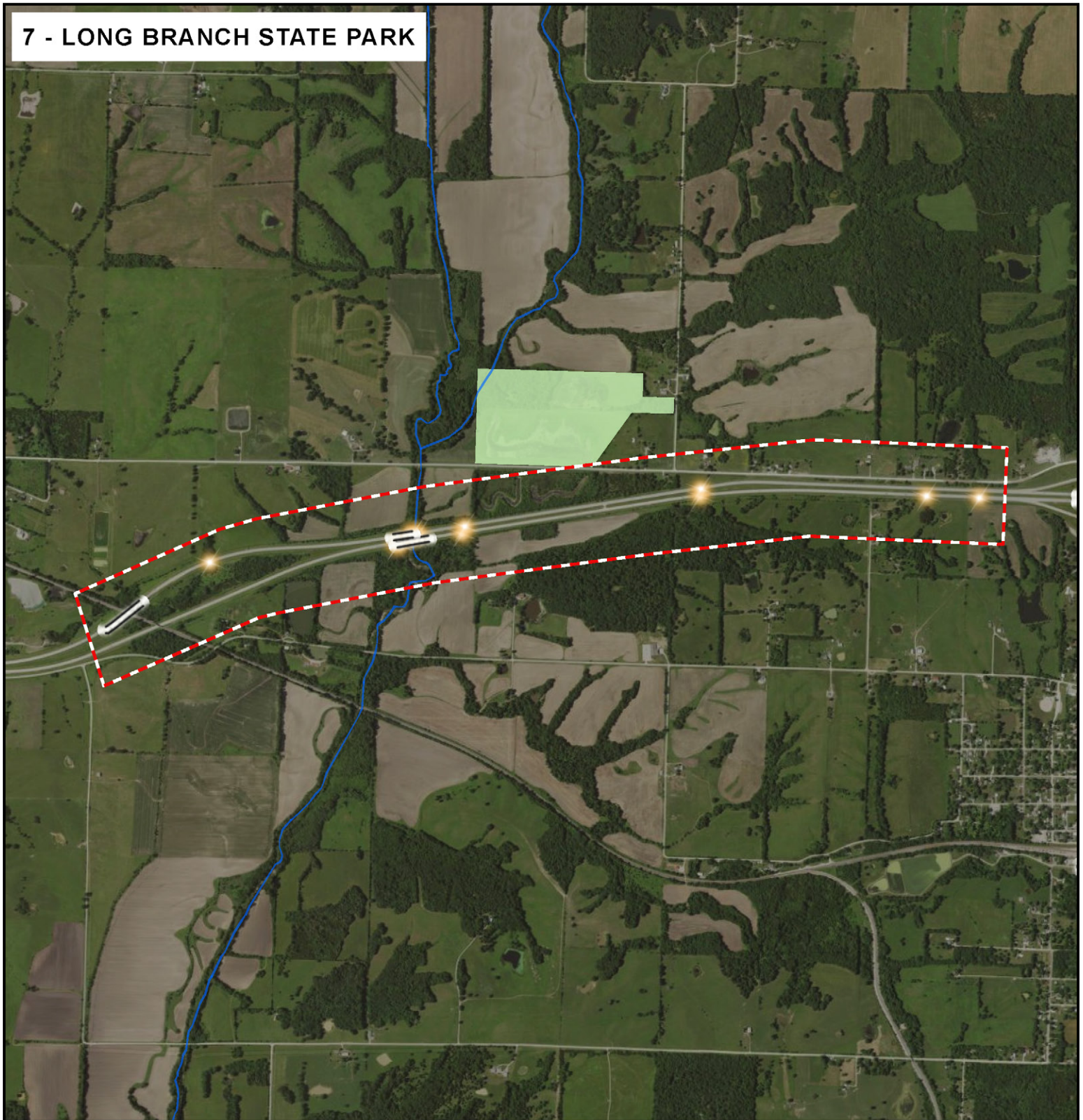
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Protected Areas
- MoDOT Bridges & Culverts
- ★ Fatal Wildlife Crashes 2019 to 2023
- ★ Wildlife Crashes 2019 to 2023



0 3 mi

7 - LONG BRANCH STATE PARK



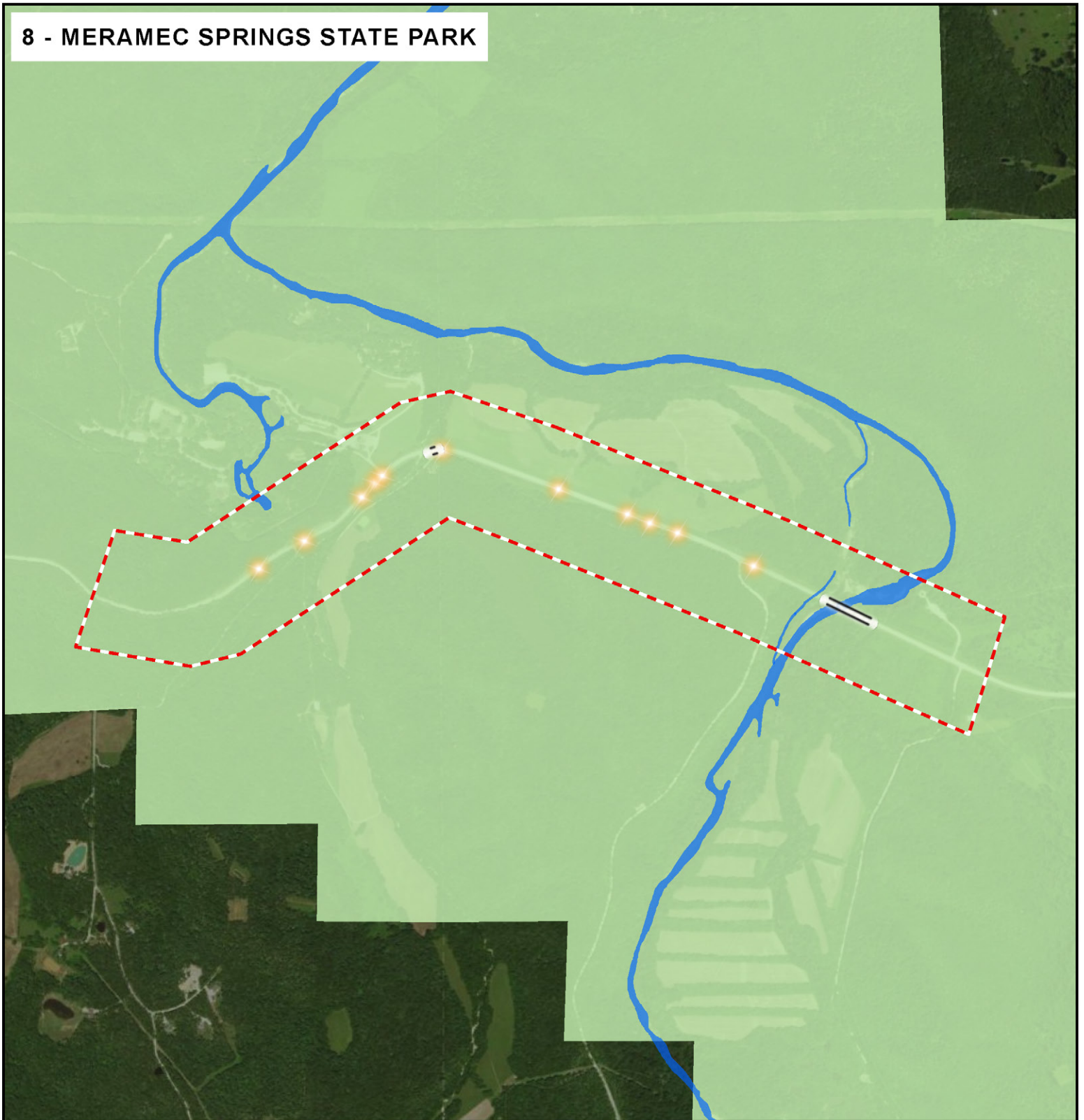
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Protected Areas
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts



0 0.8 mi

8 - MERAMEC SPRINGS STATE PARK



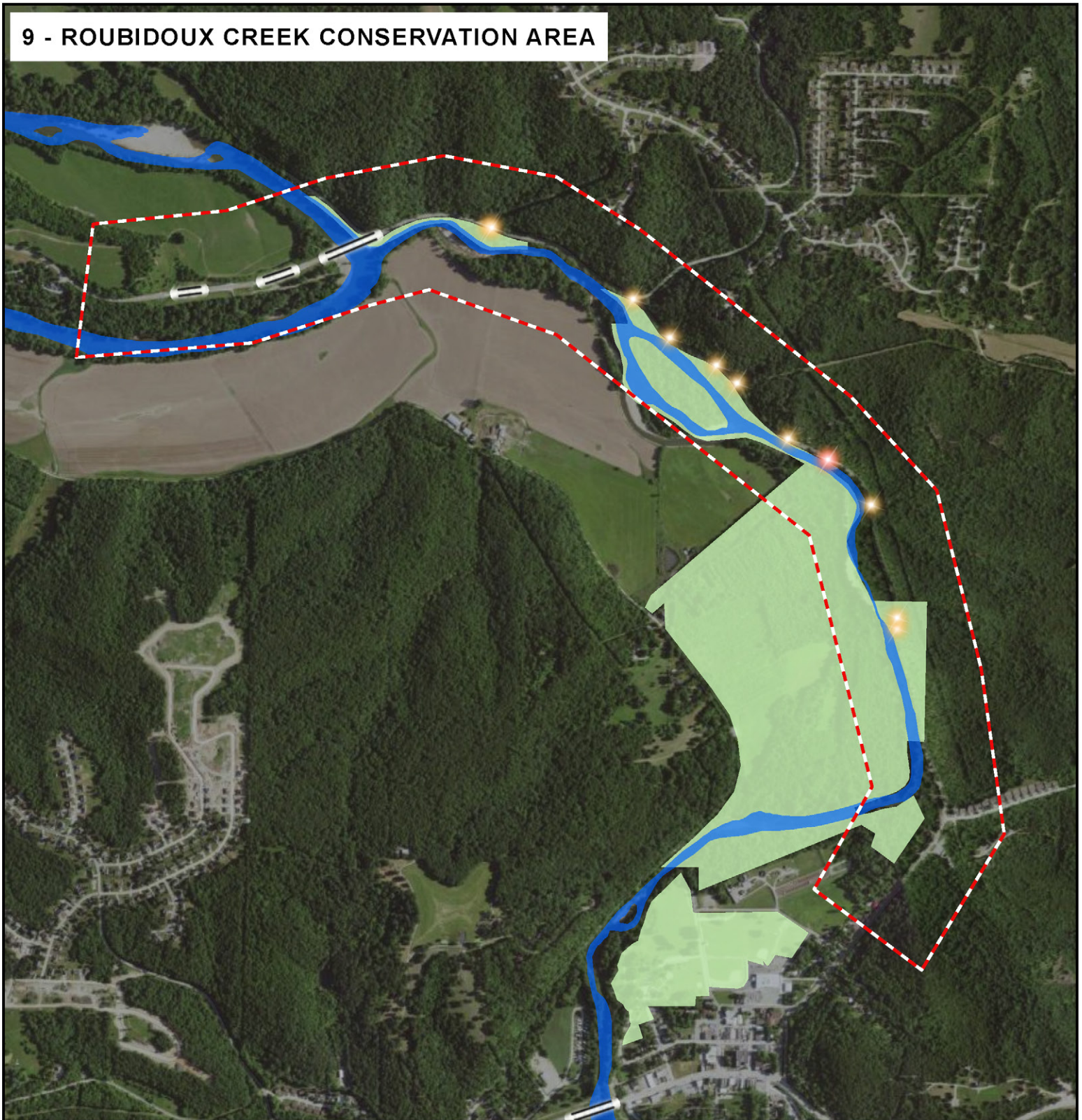
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 0.6 mi

9 - ROUBIDOUX CREEK CONSERVATION AREA



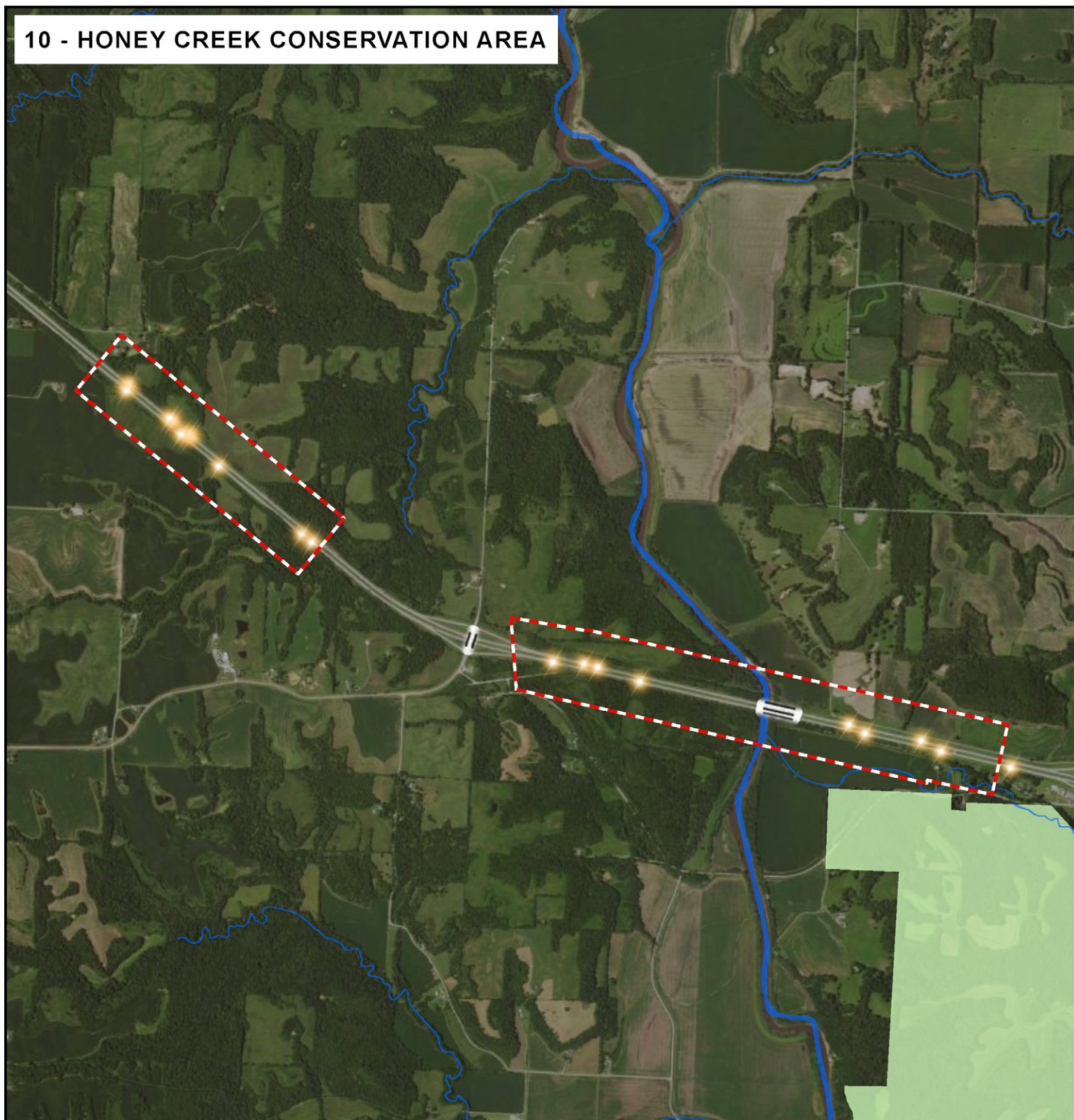
Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 0.5 mi

10 - HONEY CREEK CONSERVATION AREA



Wildlife Vehicle Collision Reduction Analysis & Hotspot Mitigation Measure Feasibility Study Top 10 Priority Segment Figures

- Top 10 Hot Spots
- Stream (NHD)
- Fatal Wildlife Crashes 2019 to 2023
- Wildlife Crashes 2019 to 2023
- MoDOT Bridges & Culverts
- Protected Areas



0 1.1 mi



H

Top 10 Environmental Review

1. Pershing State Park

The Pershing State Park Top 10 segment consists of an approximately 12-mile portion of US Route 36 within Linn County and is part of the Northwest MoDOT District.

1.1. Land Use

Land use within the Pershing State Park segment primarily consists of pasture/hay, cultivated crops, and low intensity development. Deciduous forests and woody wetlands are also commonly found throughout.

Approximately 92 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if drained and either protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance. The majority of areas deemed not prime farmland occur within Pershing State Park.

1.2. Air Quality

No permitted stationary sources of air pollution were recorded within or adjacent to the segment.

1.3. Hazardous Materials

One former Underground Storage Tank (UST) location was recorded within the segment, just south of Meadville.

1.4. Noise Sensitive Receptors

There are 95 noise receptors throughout the segment, including residential, commercial, and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

1.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land, pasture, and forest, with minimal areas of residential and commercial development.

Temporary impacts to the visual environment may occur during project construction. Any required tree clearing may permanently impact the visual environment. Resources along the segments that may be visually affected include residential buildings scattered throughout the segment and Pershing State Park.

1.6. Historic Architectural & Archaeological Resources

There are no National Register of Historic Places (NRHP) eligible or listed properties or districts within this segment. One archaeological site lies within the segment, and is unassessed for NRHP eligibility.

1.7. Terrestrial Habitat

The segment is within the Iowa and Missouri Heavy Till Plain MRLA that is spread throughout much of north-central Missouri and south-central to southeastern Iowa. This MRLA is described as loess-covered, rolling hills of clayey till, used for cropland and pasture.

1.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat (*Myotis grisescens*), Indiana bat, northern long-eared bat (*Myotis septentrionalis*), tricolored bat (*Perimyotis subflavus*), monarch butterfly (*Danaus plexippus*), and western regal fritillary (*Argynnis idalia occidentalis*). Any impacts to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The monarch butterfly may occur in areas where milkweed is present. The western regal fritillary requires high-quality prairie to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Linn County include the American bittern (*Botaurus lentiginosus*), northern harrier (*Circus hudsonius*), northern long-eared bat, Indiana bat, and prairie massasauga (*Sistrurus tergeminus tergeminus*). Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment. Priority species for this Study known to occur within the general vicinity of the segment include tricolored bat and Franklin's ground squirrel.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. While the segment largely consists of pasture/hay and cultivated crops, several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are 12 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

1.9. Section 4(f) & Section 6(f) Resources

The segment crosses Pershing State Park, which is a Section 4(f) resource. A federally-managed floodplain easement lies partially within the segment, adjacent to Pershing State Park, and a federally-managed wetland reserve easement crosses the western end of the segment. Both easements are managed by the Natural Resources Conservation Service (NRCS).

Pershing State Park was purchased using Land and Water Conservation Funds (LWCF) and is a Section 6(f) resource.

1.10. Floodplains

The segment intersects approximately 584 acres of the Locust Creek, Parson Creek, Turkey Creek, Little Turkey Creek, and an unnamed tributary of Turkey Creek 100-year floodplains.

1.11. Water Quality

Locust Creek has been submitted to the USEPA for 303(d) listing for bacteria and degraded aquatic life impairments.

Turkey Creek, Muddy Creek, and Parson Creek are all designated as Condition Unknown waterbodies for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

1.12. Wetlands & Streams

There are 147 wetland features within the segment, totaling 264 acres. These wetlands consist of ponds, riverine, emergent, and shrub/forested wetland types. Several of these features may overlap with NHD features.

There are 77 stream sections within the segment, totaling 64,522 linear feet. There are 4 named streams recorded as having perennial flow: Turkey Creek, Little Turkey Creek, Muddy Creek, and Parsons Creek intersect the segment. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other mad-made linear features used for conveying water.

1.13. Socioeconomic Factors

Two Census Tracts (CTs) intersect the segment: CT 4902 and CT 4903. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the two CTs showed that approximately 0.1 percent of households within and around the segment are a limited English-speaking household (USCB 2023b). By comparison, approximately 0.2 percent of households within Linn County and 1 percent of households within Missouri are a limited English-speaking household, indicating that the segment has a lower proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USBC 2023b).

Minority populations (people who identify as Asian or Pacific Islander, American Indian or Alaskan Native, Black (not of Hispanic origin), Hispanic, or those indicating two or more races) were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USBC 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 2 percent of the populations of CT 4902 and CT 4903 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 4 percent of the population of Linn County were identified as minority populations (USCB 2021).

CT 4902, CT 4903, and Linn County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the two CTs. Approximately 11 percent of the population of CT 4902 and 14 percent of the population of CT 4903 are below the poverty level; by comparison, 16 percent of the population of Linn County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that neither CT 4902 nor CT 4903 were identified as disadvantaged. CT 4903 was formerly identified as disadvantaged due to expected population loss rate (fatalities and injuries resulting from natural hazards each year) above the 90th percentile, however low-income populations within the CT are below the 65th percentile and thus no longer qualify as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Linn County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 3 percent of the non-employer firms in Linn County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

2. Four Rivers Conservation Area

The Four Rivers Conservation Area Top 10 segment consists of two portions of the IS-49 corridor, approximately 3 miles total, within Vernon County and is part of the Southwest MoDOT District.

2.1. Land Use

Land use within the segment primarily consists of pasture/hay, woody wetlands, cultivated crops, and low intensity development.

Approximately 85 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

2.2. Air Quality

No permitted stationary sources of air pollution were recorded within or adjacent to the segment.

2.3. Hazardous Materials

No hazardous waste sites are recorded within or adjacent to the segment.

2.4. Noise Sensitive Receptors

There are 17 noise receptors throughout the segment, including residential and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

2.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land/pasture and forest, with minimal areas of residential development.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segments that may be visually affected include residential buildings adjacent to the segment, the Hortons Bottom Natural Area, the August A. Busch Memorial Conservation Area, and the Douglas Branch Conservation Area.

2.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed historic properties or districts and no archaeological sites within this segment.

2.7. Terrestrial Habitat

The segment is within the Cherokee Prairies MRLA that is spread across the west-central border of Missouri, through the east-central to southeast portion of Kansas, and into eastern Oklahoma. This MRLA is described as gently undulating to rolling dissected plains used for cropland and pasture.

2.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, American burying beetle (*Nicrophorus americanus*), monarch butterfly, western regal fritillary, and Mead's milkweed (*Asclepias meadii*). Any impacts to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The monarch butterfly may occur in areas where milkweed is present. The American burying beetle will utilize a variety of habitats as long as specific moisture and soil requirements are met. The western regal fritillary requires high-quality prairie to persist on the landscape. Similarly, Mead's milkweed also requires high-quality remnant prairie. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Vernon County include Mead's milkweed, northern harrier, plains spotted skunk, and greater prairie-chicken (*Tympanuchus cupido*). Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. Birds of Conservation Concern (BCC) could be expected to nest within the segment, given its predominantly forested composition. There are 21 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

2.9. Section 4(f) & Section 6(f) Resources

The Hortons Bottom Natural Area and the August A. Busch Memorial Conservation Area intersect the northern portion of the segment, while the western perimeter of the southern portion of the segment is crossed by Douglas Branch Conservation Area. All three areas are Section 4(f) resources.

No Section 6(f) resources are found within the segment.

2.10. Floodplains

The segment intersects approximately 410 acres of the Little Osage River 100-year floodplain.

2.11. Water Quality

There are no waterbodies within the segment that have been submitted to the EPA for 303(d) listing. Douglas Branch is designated as a Condition Unknown waterbody for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

2.12. Wetlands & Streams

There are 66 wetland features within the segment, totaling 1,033 acres. These wetlands consist of ponds, lakes, riverine, emergent, and forested wetland types. Several of these features may overlap with NHD features.

There are 30 stream sections within the segment, totaling 22,008 linear feet. There is one named stream recorded as having perennial flow: Douglas Branch. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

2.13. Socioeconomic Factors

CT 9502 intersects the segment. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CT showed that approximately 7.8 percent of households within and around the segment are a limited English-speaking household (USCB 2023b). By comparison, approximately 1.5 percent of households within Vernon County and 1 percent of households within Missouri are a limited English-speaking household, indicating that the segment has a higher proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 3 percent of the population of CT 9502 was identified as a minority population. By comparison, approximately 20 percent of the state of Missouri and 5 percent of the population of Vernon County were identified as minority populations (USCB 2021).

CT 9502 and Vernon County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the CT. Approximately 24 percent of the population of CT 9502 is below the poverty level; by comparison, 19 percent of the population of Vernon County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 9502 is identified as disadvantaged due to housing (the share of homes without indoor kitchens or plumbing was above the 95th percentile) and legacy pollution (abandoned mine land was present in the CT), while the low-income population was above the 65th percentile (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Vernon County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 3 percent of the non-employer firms in Vernon County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

3. Wappapello Reservoir

The Wappapello Reservoir Top 10 segment consists of an approximately 3-mile portion of Missouri Route 34 within Wayne County and is part of the Southeast MoDOT District.

3.1. Land Use

Land use within the segment primarily consists of deciduous forest and pasture/hay. Development of varying intensity and forested wetlands are also commonly found throughout.

Approximately 54 percent of the soils are classified as prime farmland, prime farmland if drained, and farmland of statewide importance.

3.2. Air Quality

No permitted stationary sources of air pollution were recorded within the segment. One registered lime manufacturing facility is located approximately 0.2 miles north of the segment.

3.3. Hazardous Materials

One active petroleum facility was found on the western end of the segment. No known releases were noted for the facility.

3.4. Noise Sensitive Receptors

There are 19 noise receptors throughout the segment, including residential, commercial, and agricultural. Impacts to noise-sensitive receptors could necessitate abatement measures.

3.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land/pasture and forest, with minimal areas of residential development.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segment that may be visually affected include residential buildings and the Wappapello Lake Management Lands.

3.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed historic properties or districts within this segment. Eleven archaeological sites lie within the segment: seven are unevaluated, three are eligible, and one is not eligible for the NRHP. The three NRHP-eligible archaeological sites are 23WE696, 23WE2062, and 23WE2063. Site 23WE696 is a multicomponent site containing a Late Archaic lithic scatter, a Terminal Late Woodland habitation, and a Territorial through Early Industrial habitation. Site 23WE2062 is a precontact habitation of unknown temporal affiliation. Site 23WE2063 is an Early Woodland habitation.

3.7. Terrestrial Habitat

The segment is within the St. Francois Knobs and Basins MRLA that makes up a small portion of southeast Missouri. This MRLA is described as igneous knobs, basins, and sedimentary hills used for pasture, timber production, outdoor recreation, and tourism.

3.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, alligator snapping turtle, rabbitsfoot mussel (*Quadrula cylindrica cylindrica*), snuffbox mussel (*Epioblasma triquetra*), monarch butterfly, Big Creek crayfish (*Faxonius peruncus*), St. Francis River crayfish (*Orconectes quadruncus*), and Mead's milkweed. Any impacts to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The alligator snapping turtle is found in large, deep rivers, as well as lakes, streams, canals, and swamps. Rabbitsfoot mussels inhabit small and medium-sized creeks and some large rivers that contain gravel and sand substrates with shallow waters along the banks and reduced water velocity. The snuffbox mussel also prefers small to medium rivers but require swift currents with sand or cobble substrates. The monarch butterfly may occur in areas where milkweed is present. Both the Big Creek and St. Francis River crayfish are exclusively found within intermittent and perennial streams in the Upper St. Francis River watershed. Mead's milkweed requires high-quality prairie remnants to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

Federally designated critical habitats that overlap the segment include critical habitat for the Big Creek and St. Francis River crayfish, and the rabbitsfoot and snuffbox mussels.

State-listed species in Wayne County include American bittern, crystal darter (*Crystallaria asprella*), western fanshell mussel (*Cyprogenia aberti*), western chicken turtle, elephantear mussel (*Elliptio crassidens*), Curtis pearlymussel (*Epioblasma curtisii*), snuffbox mussel, Big Creek crayfish, St. Francis River crayfish, pink mucket mussel (*Lampsilis abrupta*), Swainson's warbler (*Limnothlypis swainsonii*), gray bat, northern long-eared bat, Indiana bat, taillight shiner (*Notropis maculatus*), mountain madtom (*Noturus eleutherus*), longnose darter (*Percina nasuta*), ebonyshell mussel (*Reginaia ebenus*), rabbitsfoot mussel, and running buffalo clover (*Trifolium stoloniferum*). Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment. Priority species for this Study known to occur within the general vicinity of the segment include long-tailed weasel.

The segment is located within the USFWS Bird Conservation Region (BCR) 24: Central Hardwoods. This BCR is dominated by oak-hickory deciduous forests. The segment is predominantly forested lands and pasture/hay; several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are nine migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

3.9. Section 4(f) & Section 6(f) Resources

The segment crosses the Wappapello Lake Management Lands, which is a Section 4(f) resource. The Wappapello Lake Section of the Ozark Trail crosses the segment at the St. Francis River bridge. The trail is also a Section 4(f) resource.

No Section 6(f) resources are found within the segment.

3.10. Floodplains

The segment intersects approximately 244 acres of the Clark Creek and St. Francis River 100-year floodplains.

3.11. Water Quality

There are no waterbodies within the segment that have been submitted to the EPA for 303(d) listing. Clark Creek is designated as a Condition Unknown waterbody for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

3.12. Wetlands & Streams

There are 24 wetland features within the segment, totaling 69 acres. These wetlands consist of ponds, riverine, and forested wetland types. Several of these features may overlap with NHD features.

There are 22 stream sections within the segment, totaling 15,721 linear feet. There is one named stream recorded as having perennial flow: Clark Creek. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths, including portions of the St. Francis River categorized as artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

3.13. Socioeconomic Factors

CT 6902 intersects the segment. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CT showed that none of the households in and around the segment are limited English-speaking households (USCB 2023b). By comparison, no households within Wayne County and 1 percent of households within Missouri are a limited English-speaking household, indicating that the segment has a similar proportion of limited English proficiency when compared to the rest of the county and a lower proportion than the state of Missouri (USBC 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USBC 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 3 percent of the population of CT 6902 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 6 percent of the population of Wayne County were identified as minority populations (USCB 2021).

CT 6902 and Wayne County were both identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the CT. Approximately 18 percent of the population of CT 6902 is below the poverty level; by comparison, 25 percent of the population of Wayne County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 6902 is identified as disadvantaged due to climate change (the expected building loss rate and expected population loss rate due to natural hazards were above the 90th percentile), energy (the average energy cost divided by household income was above the 90th percentile), and health (the share of people 18 years and old who have been told they have heart disease was above the 90th percentile), while the low-income population was above the 65th percentile (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Wayne County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 4 percent of the non-employer firms in Wayne County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

4. Whiteman Air Force Base & Knob Noster State Park

The Whiteman Air Force Base & Knob Noster State Park Top 10 segment consists of an approximately 4.5-mile portion of Route DD within Johnson County and is part of the Kansas City MoDOT District.

4.1. Land Use

Land use within the segment primarily consists of deciduous forest and low intensity development. Pasture/hay and developed open space are also commonly found throughout.

Approximately 55 percent of the soils are classified as prime farmland, prime farmland if drained, and farmland of statewide importance.

4.2. Air Quality

No permitted stationary sources of air pollution were recorded within the segment. Seven registered facilities were located within 2 miles of the segment.

4.3. Hazardous Materials

One Toxic Release Inventory site (Whiteman Air Force Base) was found within the segment. Multiple other records relating to hazardous waste sites, both with completed clean-up and in long-term stewardship programs, were noted on Whiteman Air Force Base, as well as multiple records of former and currently operating UST sites. Nine hazardous waste generators were located within two miles of the segment, and two Brownfields sites were found within one mile. Two former UST sites and one active site with no known releases were noted adjacent to the segment.

4.4. Noise Sensitive Receptors

There are 129 noise receptors throughout the segment, including residential, industrial, utility and miscellaneous, commercial, government, education, agricultural, and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

4.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of residential and commercial development, agricultural land/pasture and forest. Whiteman Airforce Base is located adjacent to the segment.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segment that may be visually affected include residential buildings and Knob Noster State Park.

4.6. Historic Architectural & Archaeological Resources

There is one NRHP listed historic site within this segment, as well as 13 archaeological sites. Of the 13 archaeological sites, 11 were unevaluated and the remaining two were determined eligible for the NRHP. The NRHP listed historic site is the Montserrat Recreation Area Bridge. The two NRHP-eligible archaeological sites include 23JO1610, a precontact lithic scatter of unknown temporal affiliation, and 23JO1632, a precontact lithic scatter of unknown temporal affiliation.

4.7. Terrestrial Habitat

The segment is within the Iowa and Missouri Deep Loess Hills MRLA that is spread across the northeastern corner of Kansas and northwest corner of Missouri, stretching northward along Nebraska border through the northwestern perimeter of Iowa. This MRLA is described as loess-covered, rolling to hilly till plains used for cropland and pasture.

4.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, monarch butterfly, and western regal fritillary. Any impacts to bridges, culverts, or trees may have an effect on the gray, Indiana, and northern long-eared bats. The monarch butterfly may occur in areas where milkweed is present. The western regal fritillary requires high-quality prairie to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

No state-listed species are noted within Johnson County; however, completion of an MDC natural heritage review would be necessary to confirm the absence of listed species and/or state designated critical habitat within this segment.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. The segment is predominantly forested; several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are 15 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

4.9. Section 4(f) & Section 6(f) Resources

The segment crosses the Knob Noster State Park, which is a Section 4(f) resource.

Knob Noster State Park is also a Section 6(f) resource.

4.10. Floodplains

The segment intersects approximately 89 acres of the McAdoo Creek, Clear Fork, and an unnamed tributary of Clear Creek 100-year floodplains.

4.11. Water Quality

Clear Fork has been submitted to the EPA for 303(d) listing for low oxygen impairments. Hickory Hill Lake, adjacent to the western terminus of the segment, is designated as a Condition Unknown

waterbody for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

4.12. Wetlands & Streams

There are 29 wetland features within the segment, totaling 48 acres. These wetlands consist of ponds, riverine, emergent, and forested wetland types. Several of these features may overlap with NHD features.

There are 11 stream sections within the segment, totaling 20,863 linear feet. There is one named stream recorded as having perennial flow: McAdoo Creek. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

4.13. Socioeconomic Factors

Three CTs intersect the segment: CT 9607.01, CT 9603.01, and CT 9800. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that none of the households in CT 9603.01, 2.4 percent of the households in CT 9607.01, and 4 percent of the households in CT 9800 are limited English-speaking households (USCB 2023b). By comparison, 0.4 percent of households within Johnson County and 1 percent of households within Missouri are limited English-speaking households, indicating that the segment has a higher proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 20 percent of the population of CT 9607.01, 8 percent of CT 9603.01, and 22 percent of CT 9800 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 13 percent of the population of Johnson County were identified as minority populations (USCB 2021).

CT 9607.01, CT 9603.01, CT 9800 and Johnson County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the three CTs. Approximately 6 percent of the population of CT 9607.01, 13 percent of the population of CT 9603.01, and 9 percent of the population of CT 9800 are below the poverty level; by comparison, 12 percent of the population of Johnson County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 9607.01, CT 9603.01, and CT 9800 are not identified as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Johnson County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 9 percent of the non-employer firms in Johnson County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms due to high sampling variability, poor response quality, or other concerns about

the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

5. Parma Woods Shooting Range

The Parma Woods Shooting Range Top 10 segment consists of an approximately 4-mile portion of IS-435 within Platte County and is part of the Kansas City MoDOT District.

5.1. Land Use

Land use within the segment primarily consists of deciduous forest, low intensity development, and pasture/hay. Developed open spaces and moderate intensity development are also commonly found throughout.

Approximately 42 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

5.2. Air Quality

No permitted stationary sources of air pollution were recorded within the segment. Three registered facilities were located within 2 miles of the Segment.

5.3. Hazardous Materials

Two operational UST sites are recorded within the segment. Neither site has known releases. The Parma Wood Shooting Range property (approximately 570 feet from the segment) is the location of the former Plattco Landfill. The property is designated as an activity and use limitation area, and the southern portion is in a long-term stewardship program. One UST tank record was noted for the landfill property.

5.4. Noise Sensitive Receptors

There are 122 noise receptors throughout the segment, including residential, commercial, assembly, agriculture, and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

5.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of residential and commercial development to the east and agricultural land/pasture to the north, west, and south.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segments that may be visually affected include residential buildings eastern border of the segment, the Parma Woods Conservation Area and Parma Woods Shooting Range (part of the Conservation Area), and the Brush Creek Trail.

5.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed properties or districts within this segment. A total of 23 archaeological sites lie within the segment. Of those 24 sites, 23 were unevaluated and one was not eligible for listing on the NRHP.

Naylor South Cemetery, also known as Goerge T. Naylor Cemetery is located at the end of Bluff Road along the Brush Creek Trail. This cemetery is still present based on user submitted photos on Google Maps from May 2025.

5.7. Terrestrial Habitat

The segment is within the Iowa and Missouri Deep Loess Hills MRLA that is spread across the northeastern corner of Kansas and northwest corner of Missouri, stretching northward along Nebraska border through the northwestern perimeter of Iowa. This MRLA is described as loess-covered, rolling to hilly till plains used for cropland and pasture.

5.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, pallid sturgeon, monarch butterfly, and western regal fritillary. Any impact to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The pallid sturgeon is a large river obligate species that inhabits the Missouri and Mississippi Rivers. The monarch butterfly may occur in areas where milkweed is present. The western regal fritillary requires high-quality prairie to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Platte County include lake sturgeon (*Acipenser fulvescens*), American bittern, flathead chub (*Platygobio gracilis*), king rail (*Rallus elegans*), pallid sturgeon, and prairie massasauga. Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this Segment. Priority species for this Study known to occur within the general vicinity of the segment include Great Plains toad.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. While the segment largely consists of residential areas, pasture/hay, and cultivated crops, several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are 13 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

5.9. Section 4(f) & Section 6(f) Resources

Parma Woods Conservation Area crosses the segment west of IS-435. The Parma Woods Shooting Range (part of the Conservation Area) lies adjacent to the western perimeter of the segment. The Brush Creek Trail, part of the Platte County Parks trail system, intersects the segment in several locations along the eastern perimeter, east of IS-435. These are all Section 4(f) resources.

No Section 6(f) resources are found within the segment.

5.10. Floodplains

The segment intersects approximately 156 acres of the Muddy Creek and Brush Creek 100-year floodplains and 29 acres of the Missouri River and Brush Creek regulatory floodways.

5.11. Water Quality

There are no waterbodies within the segment that have been submitted to the EPA for 303(d) listing. Naylor Creek and Brush Creek are designated as Condition Unknown waterbodies for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses. The portion of the Missouri River abutted by the southern terminus of the segment has been submitted to the EPA for 303(d) listing for bacteria and other microbe impairments.

5.12. Wetlands & Streams

There are 63 wetland features within the segment, totaling 53 acres. These wetlands consist of ponds, riverine, emergent, and shrub/forested wetland types. Several of these features may overlap with NHD features.

There are 47 stream sections within the segment, totaling 41,360 linear feet. There are two named streams recorded as having perennial flow: Brush Creek and Naylor Creek. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

5.13. Socioeconomic Factors

Two CTs intersect the segment: CT 303.06 and CT 304.01. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that none of the households in CT 303.06 or CT 304.01 are limited English-speaking households (USCB 2023b). By comparison, 1.1 percent of households within Platte County and 1 percent of households within Missouri are limited English-speaking households, indicating that the segment has a lower proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 8 percent of the populations of CT 304.01 and CT 303.06 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 18 percent of the population of Platte County were identified as minority populations (USCB 2021).

CT 304.01, CT 303.06, and Platte County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the two CTs. Approximately 4 percent of the population of CT 304.01 and 2 percent of the population of CT 303.06 are below the poverty level; by comparison, 7 percent of the population of Platte County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 304.01 and CT 303.06 are not identified as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Platte County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms.

Approximately 20 percent of non-employer firms (USCB 2023c) and 9 percent of employer firms (USCB 2023a) in Platte County were identified as minority-owned businesses. By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

6. Fox River & Buck Run

The Fox River and Buck Run segment consists of one portion of SH 27 (approximately 0.5 miles) in Clark County and one portion of Highway 61 (approximately 3 miles) in Lewis County. Both are part of the Northeast MoDOT District.

6.1. Land Use

Land use within the segment primarily consists of cultivated crops and deciduous forest. Pasture/hay and low intensity development are also commonly found throughout.

Approximately 78 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if drained and either protected from flooding or not frequently flooded during the growing season, prime farmland if protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

6.2. Air Quality

No permitted stationary sources of air pollution were recorded within the segment. Four registered facilities were located within 2 miles of the northern portion of the segment.

6.3. Hazardous Materials

No hazardous waste sites are recorded within the northern portion of the segment. One former UST location is within the southern portion of the segment.

6.4. Noise Sensitive Receptors

There are 19 noise receptors throughout the segment, including residential and agriculture. Impacts to noise-sensitive receptors could necessitate abatement measures.

6.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land/pasture and forest. Several residential properties occur within and adjacent to the segment.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segment that may be visually affected include residential buildings and conservation easements in the southern portion of the segment.

6.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed properties or districts within this segment. A total of 31 archaeological sites lie within the segment. Of these 31 sites, 28 were unevaluated, one was not eligible, and two were eligible for listing on the NRHP. The two eligible sites were 23LE378, an Archaic lithic scatter, and 23LE366, a Woodland habitation and quarry.

6.7. Terrestrial Habitat

The segment is within the Central Mississippi Valley Wooded Slopes MRLA that follows the Mississippi, Missouri, Ohio, Illinois, and Wabash River floodplains. This MRLA is described as deeply dissected, loess-covered hills used for cropland and pasture.

6.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, Higgins' eye mussel (*Lampsilis higginsii*), monarch butterfly, and western regal fritillary. Any impact to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The Higgins' eye mussel is found in deep waters with moderate currents and prefer stable substrates. The monarch butterfly may occur in areas where milkweed is present. The western regal fritillary requires high-quality prairie to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Clark County include lake sturgeon, Blanding's turtle, yellow mud turtle, northern long-eared bat, Indiana bat, Topeka shiner, fat pocketbook mussel (*Potamilus capax*), ebonyshell mussel, and central mudminnow (*Umbra limi*). Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment. Priority species for this Study known to occur within the general vicinity of the segment include Blanding's turtle and Kirtland's snake.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. While the segment largely consists of cultivated crops, several Birds of Conservation Concern (BCC) could be expected to nest within forested areas in the segment. There are 14 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

6.9. Section 4(f) & Section 6(f) Resources

No Section 4(f) resources are found within the segment; however, several conservation easements cross the southern portion of the segment.

No Section 6(f) resources are found within the segment.

6.10. Floodplains

The segment intersects approximately 188 acres of the Fox River and unnamed tributaries of Buck Run and Doe Run 100-year floodplains, and less than 1 acre of the Fox River regulatory floodway.

6.11. Water Quality

The western portion of the Fox River within the northern portion of the segment has been submitted to the EPA for 303(d) listing for bacteria and microbe impairments. Multiple lakes throughout the southern portion of the segment are designated as Condition Unknown waterbodies for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

6.12. Wetlands & Streams

There are 20 wetland features within the segment, totaling 32 acres. These wetlands consist of ponds, riverine, emergent, and shrub/forested wetland types. Several of these features may overlap with NHD features.

There are 14 stream sections within the segment, totaling 12,863 linear feet. There are no named streams recorded as having perennial flow. All stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

6.13. Socioeconomic Factors

Two CTs intersect the Segment: CT 9502 and CT 9701. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that none of the households in CT 9502 or CT 9701 are limited English-speaking households (USCB 2023b). None of the households within Clark or Lewis Counties are limited English-speaking households, while 1 percent of households within Missouri are limited English-speaking, indicating that the segment has a similar proportion of limited English proficiency when compared to the rest of the counties, and a lower proportion than the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 4 percent of the population of CT 9502 and 9 percent of the population of CT 9701 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri, 4 percent of the population of Clark County, and 7 percent of the population of Lewis County were identified as minority populations (USCB 2021).

CT 9502, CT 9701, Lewis County, and Clark County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the two CTs. Approximately 12 percent of the population of CT 9502 and 14 percent of the population of CT 9701 are below the poverty level; by comparison, 15 percent and 9 percent of the population of Lewis and Clark Counties, respectively, are below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 9502 was previously identified as disadvantaged due to climate change (the expected building loss rate and expected population loss rate due to natural hazards, and the projected flood risk were above the 90th percentile), housing (the lack of indoor plumbing was above the 90th percentile), transportation (transportation barriers was above the 90th percentile), and workforce development (percent of people 25 years or older whose high school education is less than a high school diploma was above 10 percent). However, while the low-income population was below the 65th percentile and no other workforce development factors were above the 90th percentile, thus the CT no longer qualifies as disadvantaged (CEJST 2024).

CT 9701 was identified as disadvantaged due to climate change (the expected population loss rate due to natural hazards was above the 90th percentile) and wastewater discharge (modeled toxic concentrations at parts of streams within 500 meters were above the 90th percentile), while the low-income population was above the 65th percentile (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Lewis and Clark Counties using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 3 percent of the non-employer firms in Lewis County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms in Lewis or Clark Counties (USCB 2023a), or for minority-owned non-employer firms in Clark County (USCB 2023c) due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection. By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

7. Long Branch State Park

The Long Branch State Park Top 10 segment consists of an approximately 2-mile portion of US Route 36, within Macon County and is part of the Northeast MoDOT District.

7.1. Land Use

Land use within the segment primarily consists of pasture/hay. Low intensity development is also found throughout, as well as minor areas of forested land.

Within the segment, approximately 65 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if drained and either protected from flooding or not frequently flooded during the growing season, prime farmland if protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

7.2. Air Quality

No permitted stationary sources of air pollution were recorded within or adjacent to the segment.

7.3. Hazardous Materials

No hazardous waste sites are recorded within the segment. One UST location is within 0.3 miles of the northeastern corner of the segment; the site was issued a No Further Action letter without restriction. One RCRA hazardous waste site is located within 0.3 miles of the southeast corner of the segment.

7.4. Noise Sensitive Receptors

There are 23 noise receptors throughout the segment, including residential and agriculture. Impacts to noise-sensitive receptors could necessitate abatement measures.

7.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land/pasture and forest, with minimal areas of residential development.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segments that may be visually affected include residential buildings throughout the segment, and the conservation easement to the north.

7.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed properties or districts within this segment. There are five archaeological sites, all of which have been determined not eligible for the NRHP.

The Gregory Cemetery is located adjacent to Old U.S. 61 at latitude/longitude 40.21830, -91.52810. This cemetery consists of at least six bases of headstones and is thought to have been destroyed when U.S. Highway 61 was built.

7.7. Terrestrial Habitat

The segment is within the Iowa and Missouri Heavy Till Plain MRLA that is spread throughout much of north-central Missouri and south-central to southeastern Iowa. This MRLA is described as loess-covered, rolling hills of clayey till, used for cropland and pasture.

7.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, monarch butterfly, and western regal fritillary. Any impacts to bridges, culverts, or trees may have an effect on the gray and Indiana bats. The monarch butterfly may occur in areas where milkweed is present. The western regal fritillary requires high-quality prairie to persist on the landscape. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Macon County include American bittern, northern harrier, northern long-eared bat, and Indiana bat. Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. While the segment largely consists of pasture/hay, several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are four migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

7.9. Section 4(f) & Section 6(f) Resources

No Section 4(f) resources are found within the segment; however, a conservation easement lies to the north of the segment.

No Section 6(f) resources are found within the segment.

7.10. Floodplains

The segment intersects approximately 145 acres of the Middle Fork Chariton River and its unnamed tributary.

7.11. Water Quality

There are no waterbodies within the segment that have been submitted to the EPA for 303(d) listing. The Middle Fork Little Chariton River is designated as Condition Unknown waterbodies for aquatic life, fish and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

7.12. Wetlands & Streams

There are 34 wetland features within the segment, totaling 37 acres. These wetlands consist of ponds, riverine, emergent, and shrub/forested wetland types. Several of these features may overlap with NHD features.

There are nine stream sections within the segment, totaling 12,786 linear feet. There is one named stream recorded as having perennial flow: the Middle Fork Little Chariton River. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

7.13. Socioeconomic Factors

Two CTs intersect the segment: CT 9602 and CT 9603. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that 0.1 percent of the households in CT 9602 and none of the households in CT 9603 are limited English-speaking households (USCB 2023b). By comparison, 0.1 percent of households within Macon County and 1 percent of households within Missouri are limited English-speaking households, indicating that the segment has a similar proportion of limited English proficiency when compared to the rest of the county and a lower proportion than the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 2 percent of the population of CT 9602 and 3 percent of the population of CT 9603 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 7 percent of the population of Macon County were identified as minority populations (USCB 2021).

CTs 9602 and 9603 were identified as APPs, per the 2025-2026 MPDG. Macon County was not identified as an APP (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the two CTs. Approximately 9 percent of the population of CT 9602 and 7 percent of the population of CT 9603 are below the poverty level; by comparison, 10 percent of the population of Macon County is below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CT 9602 is identified as disadvantaged due to health (the share of people 18 years and old who have been told they have heart disease was above the 90th percentile), housing (homes lacking indoor plumbing was above the 90th percentile), legacy pollution (one or more abandoned mines were present within the CT), and transportation (transportation barriers were above the 90th percentile), while the low-income population was above the 65th percentile. CT 9603 was not identified as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Macon County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 5 percent of the non-employer firms in Macon County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison,

approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

8. Maramec Springs State Park

The Maramec Springs State Park Top 10 segment consists of an approximately 2-mile portion of Missouri Route 8, within Crawford and Phelps Counties and lies within the Central MoDOT District.

8.1. Land Use

Land use within the segment primarily consists of deciduous forest. Small areas of development of varying intensity and pasture/hay are also found throughout.

Within the segment, approximately 49 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if protected from flooding or not flooded frequently during the growing season, and farmland of statewide importance.

8.2. Air Quality

No permitted stationary sources of air pollution were recorded within or adjacent to the segment.

8.3. Hazardous Materials

One former UST site was recorded within the segment.

8.4. Noise Sensitive Receptors

There are four noise receptors throughout the segment, including residential and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

8.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of forested land with a few areas of pasture/hay and several residential structures.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segments that may be visually affected include residential buildings, Maramec Springs Trout Park, and the Woodson K. Woods Memorial Conservation Area.

8.6. Historic Architectural & Archaeological Resources

One NRHP district lies partially within this segment. There are also five archaeological sites within the segment. Of these, two are unevaluated, two are eligible, and one is not eligible for listing on the NRHP. The eligible historic district is the Meramec Iron Works District. The two eligible archaeological sites are 23CR437, a multicomponent site consisting of a precontact lithic scatter and a historic commercial/industrial site, and 23CR241, for which site details were not available.

8.7. Terrestrial Habitat

The segment is within the Ozark Highland MRLA that is spread across southwest Missouri, northern Arkansas, and northeastern Oklahoma. This MRLA is described as deeply dissected

plateau underlain by limestone, dolostone, and shale. Topography consists of karst, with elevations ranging from 300 feet to 1,600 feet. Area physiography ranges from steeply sloping wooded hills and gravelly valleys to the south to gently rolling prairie uplands to the north.

8.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, eastern hellbender (*Cryptobranchus alleganiensis*), salamander mussel (*Simpsonaias ambigua*), Hine's emerald dragonfly (*Somatochlora hineana*), and monarch butterfly. Any impact to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The eastern hellbender is found in perennial streams and rivers that contain large, flat rocks. The salamander mussel prefers rivers, streams, and lakes with natural flow regimes. Hine's emerald dragonflies require spring fed meadows, wet meadows, and marshes. The monarch butterfly may occur in areas where milkweed is present. A field survey would be necessary to confirm the presence of habitat for these species.

Federally designated critical habitat for the Indiana bat overlaps the segment. Federally designated critical habitat for the Hine's emerald dragonfly is present within Phelps County.

State-listed species in Crawford and Phelps Counties include eastern hellbender, crystal darter, spectaclecase mussel (*Cumberlandia monodonta*), snuffbox mussel, gray bat, northern long-eared bat, Indiana bat, tricolored bat, Hine's emerald dragonfly, plains spotted skunk, sheepsnose mussel (*Plethobasus cyphus*), scaleshell mussel (*Potamilus leptodon*), and running buffalo clover. Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment.

The segment is located within the USFWS Bird Conservation Region (BCR) 24: Central Hardwoods. This BCR is dominated by oak-hickory deciduous forests. The segment is predominantly forested; Birds of Conservation Concern (BCC) are expected to nest within the segment. There are 14 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

8.9. Section 4(f) & Section 6(f) Resources

The segment lies within Maramec Springs Trout Park. The Woodson K. Woods Memorial Conservation Area also crosses the eastern end of the segment. These are both Section 4(f) resources.

No Section 6(f) resources are found within the segment.

8.10. Floodplains

The segment intersects approximately 122 acres of the Meramec River 100-year floodplain.

8.11. Water Quality

There are no waterbodies within the segment that have been submitted to the EPA for 303(d) listing. Asher Hollow Creek is designated as Condition Unknown waterbodies for aquatic life, fish

and shellfish consumption, swimming and boating, and other uses, which means the water quality has not been assessed for the identified uses.

8.12. Wetlands & Streams

There are 27 wetland features within the segment, totaling 37 acres. These wetlands consist of ponds, riverine, emergent, and shrub/forested wetland types. Several of these features may overlap with NHD features.

There are 11 stream sections within the segment, totaling 12,188 linear feet. There is one named stream recorded as having perennial flow: Meramec River. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

8.13. Socioeconomic Factors

Three CTs intersect the segment: CT 8901, CT 8910, and CT 4504.01. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that none of the households in CT 8901, 8910, or 4504.01 are limited English-speaking households (USCB 2023b). By comparison, 0.1 percent of households within Crawford County, 1.2 percent of households within Phelps County, and 1 percent of households within Missouri are limited English-speaking households, indicating that the segment has a lower proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 6 percent of the population of CT 8901, 12 percent of the population of CT 8910, and 4 percent of the population of CT 4504.01 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri, 5 percent of the population of Crawford County, and 11 percent of the population of Phelps County were identified as minority populations (USCB 2021).

CTs 8901 and 8910 were identified as APPs, per the 2025-2026 MPDG. CT 4504.01, Phelps County, and Crawford County were not identified as APPs (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the three CTs. Approximately 10 percent of the population of CT 8901, 7 percent of the population of CT 8910, and 18 percent of CT 4504.01 are below the poverty level; by comparison, 17 percent of the population of Phelps County and 14 percent of Crawford County are below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that CTs 8901 is identified as disadvantaged due to legacy pollution (one or more formerly used defense sites were present within the CT), while the low-income population was above the 65th percentile. CT 8910 was not identified as disadvantaged (CEJST 2024).

CT 4504.01 was formerly identified as disadvantaged due to expected population loss rate (fatalities and injuries resulting from natural hazards each year) above the 90th percentile, energy (average annual energy cost above the 90th percentile), and workforce development (percent of people over 25 whose high school education is less than a high school diploma) above 10 percent. However, low-income populations within the CT are below the 65th percentile and thus no longer qualify as disadvantaged (CEJST 2024).

County-level data minority-owned businesses was reviewed for Phelps and Crawford County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 9 percent of the non-employer firms in Phelps County and 6 percent of non-employer firms in Crawford County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned employer firms in Phelps or Crawford Counties due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

9. Roubidoux Creek Conservation Area

The Roubidoux Creek Conservation Area Top 10 segment consists of an approximately 2.5-mile portion of Missouri Route 17 within Pulaski County and is part of the Central MoDOT District.

9.1. Land Use

Land use within the segment predominantly consists of deciduous forest.

Within the segment, approximately 28 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

9.2. Air Quality

One permitted stationary source of air pollution, a laundry and dry-cleaning facility, was recorded within the segment. One registered facility was located within 1 mile of the segment.

9.3. Hazardous Materials

One former UST location is recorded on a property crossed by the southwest corner of the segment. The exact location of the former tank is unknown.

9.4. Noise Sensitive Receptors

There are 23 noise receptors throughout the segment, including residential, industrial, and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

9.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of forested lands with several areas of agricultural land/pasture. Residential development intersects the eastern perimeter of the segment in several areas.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segment that may be visually affected include residential buildings along the eastern perimeter, and the Roubidoux Creek Conservation Area which intersects much of the segment.

9.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed historic properties or districts within this segment. There are seven archaeological sites, all of which are unevaluated for listing on the NRHP.

9.7. Terrestrial Habitat

The segment is within the Ozark Highland MRLA that is spread across southwest Missouri, northern Arkansas, and northeastern Oklahoma. This MRLA is described as deeply dissected plateau underlain by limestone, dolostone, and shale. Topography consists of karst, with elevations ranging from 300 feet to 1,600 feet. Area physiography ranges from steeply sloping wooded hills and gravelly valleys to the south to gently rolling prairie uplands to the north.

9.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the gray bat, Indiana bat, northern long-eared bat, tricolored bat, eastern hellbender, scaleshell mussel, spectaclecase mussel, and monarch butterfly. Any impacts to bridges, culverts, or trees may have an effect on the gray, Indiana, northern long-eared, and tricolored bats. The eastern hellbender is found in perennial streams and rivers that contain large, flat rocks. Scaleshell mussels require clear, fast-moving streams and rivers containing gravel or sand substrates, while spectaclecase mussels prefer sheltered areas, such as underneath rock slabs, tree roots, or between boulders, of large rivers with muddy substrates. The monarch butterfly may occur in areas where milkweed is present. A field survey would be necessary to confirm the presence of habitat for these species.

Federally designated critical habitat for the spectaclecase mussel overlaps the segment.

State-listed species in Pulaski County include slippershell mussel (*Alasmidonta viridis*), eastern hellbender, crystal darter, spectaclecase mussel, elephantear mussel, gray bat, northern long-eared bat, Indiana bat, scaleshell mussel, and plains spotted skunk. Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment.

The segment is located within the USFWS Bird Conservation Region (BCR) 24: Central Hardwoods. This BCR is dominated by oak-hickory deciduous forests. The segment is predominantly forested; Birds of Conservation Concern (BCC) are expected to nest within the segment. There are 12 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

9.9. Section 4(f) & Section 6(f) Resources

The Roubidoux Creek Conservation Area, a 4(f) resource, intersects the segment.

No Section 6(f) resources are found within the segment. Roubidoux Park, a 6(f) resource owned by the City of Waynesville, lies approximately 300 feet to the southwest of the segment.

9.10. Floodplains

The segment intersects approximately 162 acres of the Roubidoux Creek and Gasconade River 100-year floodplain and 58 acres of the Roubidoux Creek regulatory floodway.

9.11. Water Quality

The Gasconade River has been submitted to the EPA for 303(d) listing for mercury, bacteria, and microbe impairments.

9.12. Wetlands & Streams

There are 27 wetland features within the segment, totaling 40 acres. These wetlands consist of ponds, riverine, emergent, and forested/shrub wetland types. Several of these features may overlap with NHD features.

There are 21 stream sections within the segment, totaling 18,679 linear feet. There are two named streams recorded as having perennial flow: Roubidoux Creek and Gasconade River that intersect the segment. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

9.13. Socioeconomic Factors

Two CTs intersect the segment: CT 4701.02 and CT 4704.02. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that 1 percent of the households in CT 4701.02 and CT 4704.02 are limited English-speaking households (USCB 2023b). By comparison, 1 percent of households within Pulaski County and Missouri are limited English-speaking households, indicating that the segment has a similar proportion of limited English proficiency when compared to the rest of the county and the state of Missouri (USCB 2023b).

Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 5 percent of the population of CT 4701.02 and 26 percent of the population of CT 4704.02 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri and 26 percent of the population of Pulaski County were identified as minority populations (USCB 2021).

CT 4701.02 was identified as an APP, per the 2025-2026 MPDG. CT 4704.02 and Pulaski County were not identified as APPs (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the CT. Approximately 13 percent of the population of CT 4701.02 is below the poverty level; 13 percent of the population of Pulaski County is also below the poverty level (USCB 2023d).

The archived version of the CEJST tool showed that neither CT 4701.02 or CT 4704.02 were identified as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Pulaski County using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 15 percent of the non-employer firms (USCB 2023c) and 1 percent of employer firms (USCB 2023a) in Pulaski County were identified as minority-owned businesses. By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).

10. Honey Creek Conservation Area

The Honey Creek Conservation Area Top 10 segment consists of two portions of the IS-29 corridor, approximately 4 miles total, within Holt and Andrew Counties and is part of the Northwest MoDOT District.

10.1. Land Use

Land use within the segment primarily consists of deciduous forest (found predominantly within riparian zones) and pasture/hay. Development of varying intensity and cultivated crops are also commonly found throughout.

Within the segment, approximately 68 percent of the soils are classified as prime farmland, prime farmland if drained, prime farmland if drained and either protected from flooding or not frequently flooded during the growing season, and farmland of statewide importance.

10.2. Air Quality

No permitted stationary sources of air pollution were recorded within or adjacent to the segment.

10.3. Hazardous Materials

No hazardous waste sites are recorded within the segment. One active Underground Storage Tank (UST) location is within 0.5 miles of the eastern end of the southeast portion of the segment, and one former UST location is within 0.2 miles of the western end of the southeast portion of the segment.

10.4. Noise Sensitive Receptors

There are six noise receptors throughout the segment, including residential, agriculture, and several receptors of unknown classification. Impacts to noise-sensitive receptors could necessitate abatement measures.

10.5. Visual Environment

Desktop review of aerial imagery within and adjacent to the segment shows that much of the surrounding area consists of agricultural land/pasture and forest, with minimal areas of residential and commercial development.

Temporary impacts to the visual environs may occur during project construction. Any required tree clearing may permanently impact the visual environs. Resources along the segments that may be visually affected include residential buildings on the northern corner of the northwest portion of the segment, and the Honey Creek Conservation Area which is adjacent to the southeastern portion of the segment.

10.6. Historic Architectural & Archaeological Resources

There are no NRHP eligible or listed properties or districts within this segment. There are three archaeological sites, none of which have been assessed for NRHP listing eligibility.

10.7. Terrestrial Habitat

The segment is within the Iowa and Missouri Deep Loess Hills MRLA that is spread across the northeastern corner of Kansas and northwest corner of Missouri, stretching northward along Nebraska border through the northwestern perimeter of Iowa. This MRLA is described as loess-covered, rolling to hilly till plains used for cropland and pasture.

10.8. Threatened & Endangered Species

Federally protected species whose habitat range is within the segment include the Indiana bat, northern long-eared bat, tricolored bat, and monarch butterfly. Any impacts to bridges, culverts, or trees may have an effect on the Indiana, northern long-eared, and tricolored bats. The monarch butterfly may occur in areas where milkweed is present. A field survey would be necessary to confirm the presence of habitat for these species.

State-listed species in Andrew and Holt Counties include lake sturgeon, American bittern, Blanding's turtle, western prairie fringed orchid (*Platanthera praeclara*), flathead chub, king rail, pallid sturgeon, and prairie massasauga. Completion of an MDC natural heritage review would be necessary to confirm the presence of range and/or state designated critical habitat within this segment. Priority species for this Study known to occur within the general vicinity of the segment include American badger.

The segment is located within the USFWS Bird Conservation Region (BCR) 22: Eastern Tallgrass Prairie. Large areas of this BCR have been converted for agricultural and urban uses. The segment largely consists of forested lands and pasture/hay; several Birds of Conservation Concern (BCC) could be expected to nest within the segment. There are 7 migratory BCCs that may occur within or in proximity to the segment, including the bald eagle.

10.9. Section 4(f) & Section 6(f) Resources

No Section 4(f) resources are found within the segment; however, Honey Creek Conservation Area lies adjacent to the south of the southeastern portion of the segment.

No Section 6(f) resources are found within the segment.

10.10. Floodplains

The southeastern portion of the segment intersects 79 acres of the Nodaway River 100-year floodplain.

10.11. Water Quality

Nodaway River was removed from the 303(d) list for bacteria and microbe impairments in 2022. The waterbody is still considered impaired; however, restoration plans have been developed, and Total Maximum Daily Loads (TMDLs) are in place.

10.12. Wetlands & Streams

There are 30 wetland features within the segment, totaling 39 acres. These wetlands consist of ponds, riverine, emergent, and forested wetland types. Several of these features may overlap with NHD features.

There are seven stream sections within the segment, totaling 5,520 linear feet. There are three named streams recorded as having perennial flow: Honey Creek, Meade Creek, and a channelized portion of Nodaway River intersect the segment. The remaining stream sections are recorded as having intermittent flow or are considered artificial paths. Artificial paths are culverts, ditches, or other man-made linear features used for conveying water.

10.13. Socioeconomic Factors

Two CTs intersect the segment: CT 103 and CT 9603. The ACS Detailed Household Language by Household Limited English-Speaking Status 2023 5-Year Estimate table for the CTs showed that none of the households in CT 103 or CT 9603 are limited English-speaking households (USCB 2023b). None of households within Andrew or Holt Counties and 1 percent of the households in Missouri are limited English-speaking, indicating that the segment has a similar proportion of limited English proficiency when compared to the rest of the counties and a lower proportion than the state of Missouri (USCB 2023b).

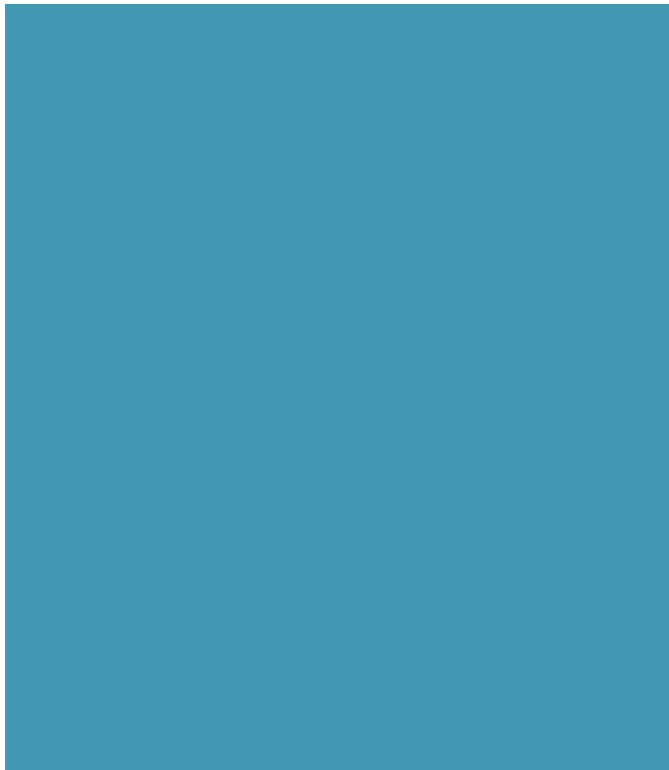
Minority populations were reviewed for the CTs intersecting the segment using the ACS 2021 5-Year Estimates Total Population table (USCB 2021). Those reporting White Alone were counted as non-minorities. All other race categories were included in the minority population estimate. Approximately 4 percent of the populations of CT 103 and CT 9603 were identified as minority populations. By comparison, approximately 20 percent of the state of Missouri, 6 percent of the population of Andrew County, and 4 percent of the population of Holt County were identified as minority populations (USCB 2021).

CT 103, CT 9603, Andrew County, and Holt County were not identified as APPs, per the 2025-2026 MPDG (USDOT 2024). The 2023 USCB ACS 5-Year Estimate table for Poverty Status in the Past 12 Months was reviewed for the two CTs. Approximately 12 percent of the population of CT 103 and 12 percent of the population of CT 9603 are below the poverty level; by comparison, 7 percent of the population of Andrew County and 10 percent of Holt County are below the poverty level (USCB 2023d).

An archived version of the CEJST tool showed that CT 9603 is identified as partially disadvantaged because the lands of Federally Recognized Tribes that cover less than 1 percent of this CT are considered disadvantaged. CT 103 was not identified as disadvantaged (CEJST 2024).

County-level data for minority-owned businesses was reviewed for Andrew and Holt Counties using the USCB Annual Business Survey (ABS) 2023 table, including both employer and non-employer firms. Approximately 5 percent of the non-employer firms in Andrew County were identified as minority-owned businesses (USCB 2023c). No estimate was available for minority-owned non-employer firms in Holt County (USCB 2023c) or employer firms in Andrew or Holt

Counties due to high sampling variability, poor response quality, or other concerns about the estimate quality during the period of data collection (USCB 2023a). By comparison, approximately 12 percent of the employer firms and 17 percent of the non-employer firms in the state of Missouri were identified as minority-owned businesses (USCB 2023a; USCB 2023c).



Undercrossing Design Plans



PROJECT SUMMARY

LOCAL BRIDGE CONSULTANT

- NAME = Todd Black
- EMAIL = Todd.Black@conteches.com
- PHONE NUMBER = 913-216-3818

STRUCTURE DETAILS

- SPAN = 32' - 0"
- PRECAST RISE = 11' - 0 3/4"
- LENGTH = 72 FT.

HEADWALLS

- INLET HEADWALL HEIGHT = 2 FT.
- OUTLET HEADWALL HEIGHT = 2 FT.

FOUNDATIONS

- FOUNDATION TYPE = STRIP

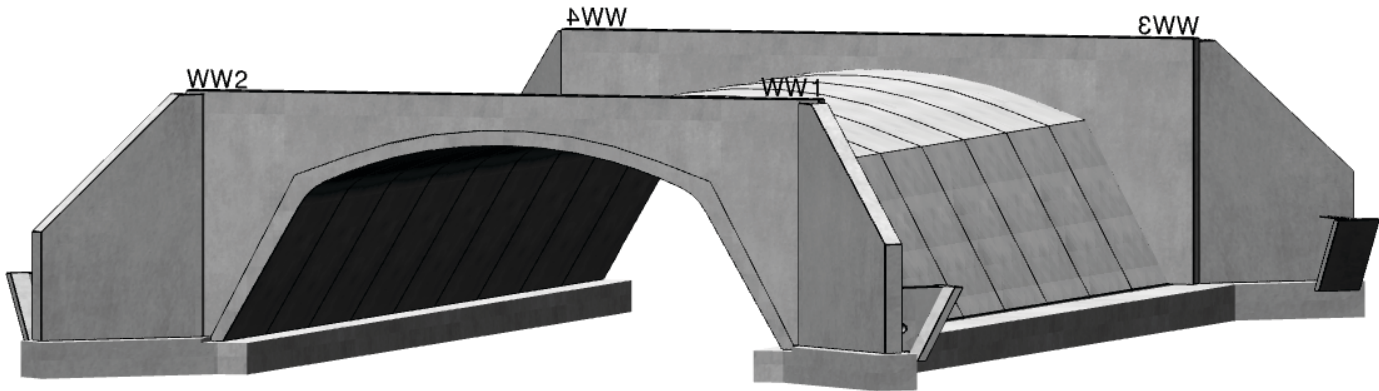
WINGWALLS

- WW 1 ANGLE = 45 DEG.
- WW 1 LENGTH = 10 FT.
- WW 1 HIGH HEIGHT = 13.4 FT.
- WW 1 LOW HEIGHT = 6 FT.
- WW 2 ANGLE = 45 DEG.
- WW 2 LENGTH = 10 FT.
- WW 2 HIGH HEIGHT = 13.4 FT.
- WW 2 LOW HEIGHT = 6 FT.
- WW 3 ANGLE = 45 DEG.
- WW 3 LENGTH = 10 FT.
- WW 3 HIGH HEIGHT = 13.4 FT.
- WW 3 LOW HEIGHT = 6 FT.
- WW 4 ANGLE = 45 DEG.
- WW 4 LENGTH = 10 FT.
- WW 4 HIGH HEIGHT = 13.4 FT.
- WW 4 LOW HEIGHT = 6 FT.

NOTES

1. THIS BRIDGE HAS BEEN DESIGNED FOR GENERAL SITE CONDITIONS. THE PROJECT ENGINEER SHALL BE RESPONSIBLE FOR THE STRUCTURE'S SUITABILITY TO THE EXISTING SITE CONDITIONS AND FOR THE HYDRAULIC EVALUATION -- INCLUDING SCOUR AND CONFIRMATION OF SOIL CONDITIONS.
2. PRIOR TO CONSTRUCTION, CONTRACTOR MUST VERIFY ALL ELEVATIONS SHOWN THROUGH THE ENGINEER.
3. ONLY CONTECH ENGINEERED SOLUTIONS LLC, THE CONSPAN APPROVED MANUFACTURER IN THE PROJECT STATE MAY PROVIDE THE STRUCTURE DESIGNED IN ACCORDANCE WITH THESE PLANS.
4. THIS DYOB DRAWING IS A CONCEPTUAL DESIGN. PLEASE WORK WITH YOUR LOCAL BRIDGE CONSULTANT FOR FURTHER SOLUTION DEVELOPMENT AND PRICING.
5. THE USE OF ANOTHER PRECAST STRUCTURE WITH THE DESIGN ASSUMPTIONS USED FOR THE CON/SPAN® STRUCTURE MAY LEAD TO SERIOUS DESIGN ERRORS. USE OF ANY OTHER PRECAST STRUCTURE WITH THIS DESIGN AND DRAWINGS VOIDS ANY CERTIFICATION OF THIS DESIGN AND WARRANTY. CONTECH ENGINEERED SOLUTIONS ASSUMES NO LIABILITY FOR DESIGN OF ANY ALTERNATE OR SIMILAR TYPE STRUCTURES.

CON/SPAN O-Series DYOB
Animal tunnel



PRELIMINARY
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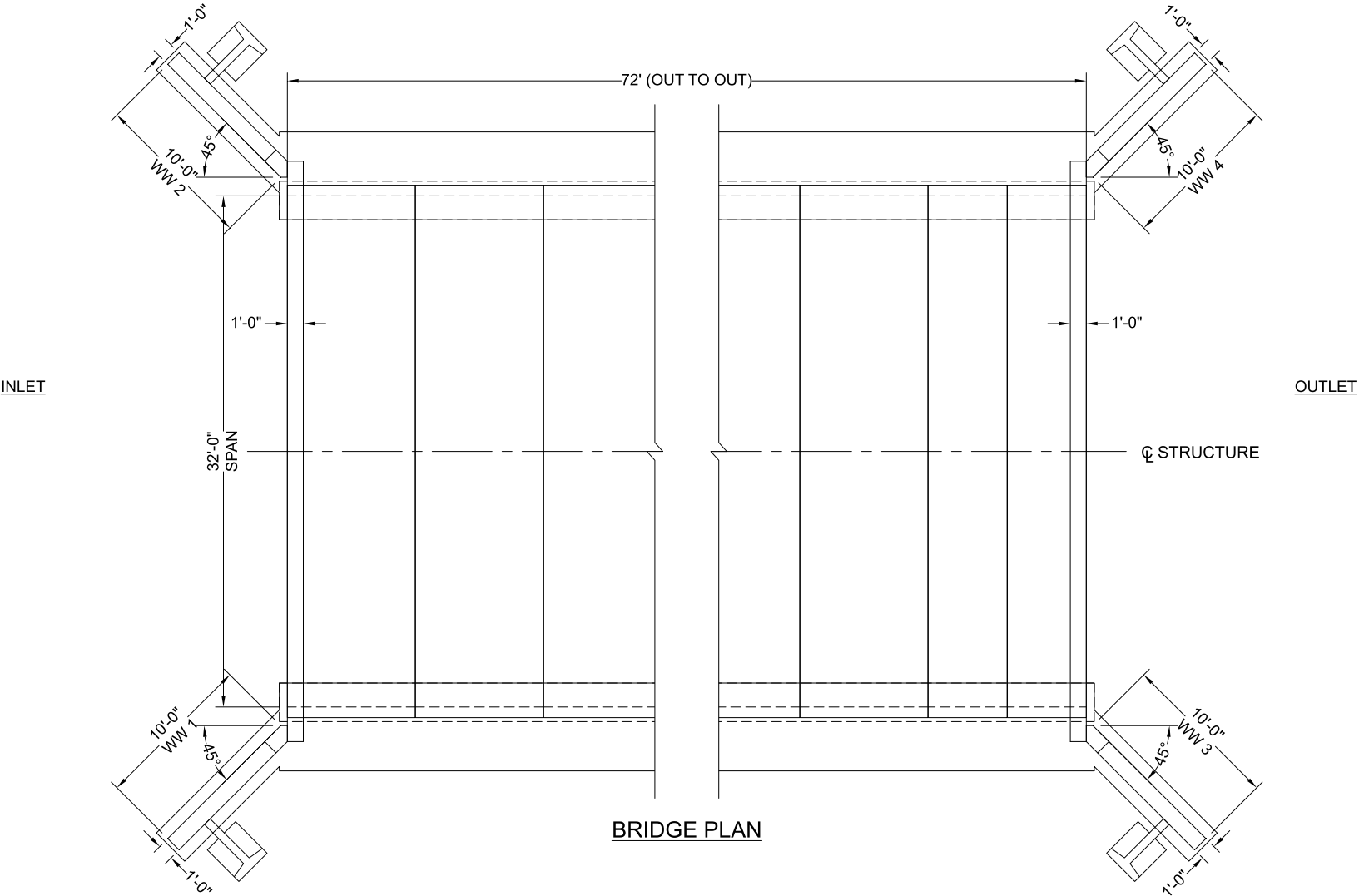
9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069
800-338-1122 513-645-7000 513-645-7993 FAX

CON/SPAN
O-SERIES

DYOB
DRAWING

DYO89599, Knob Naster State Park
Animal tunnel
Warrensburg, MO
O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65331	DYO No.: 89599	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.:	D1	OF D9



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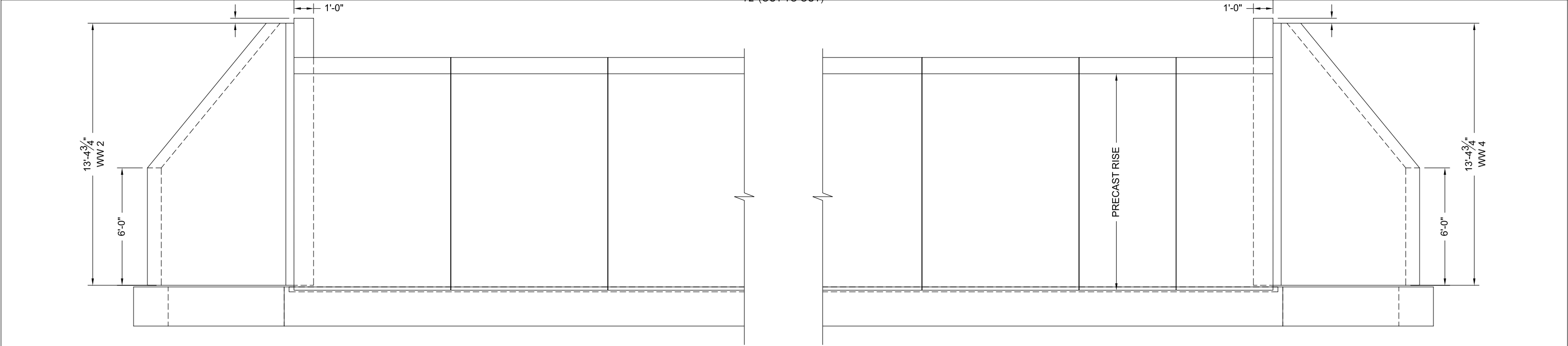


CONSPAN
O-SERIES

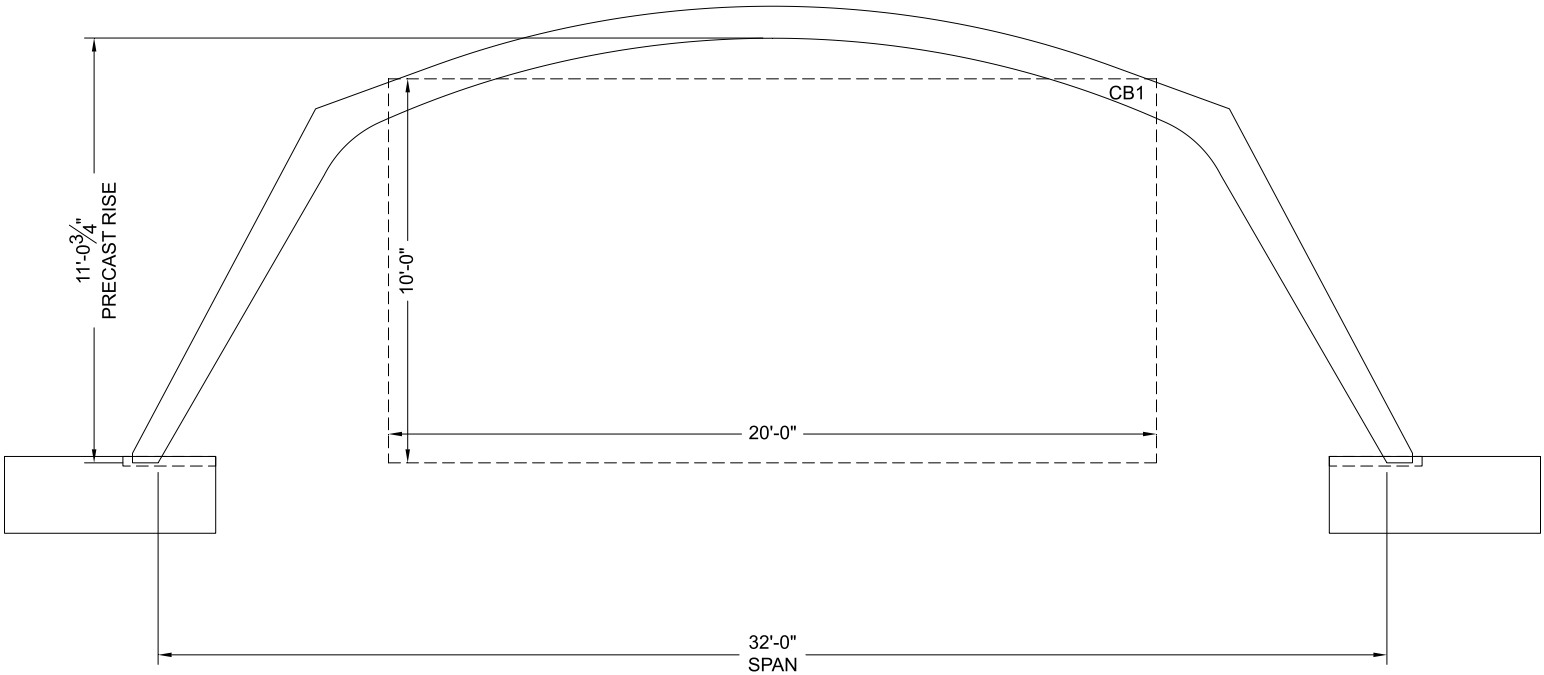
DYOB
DRAWING

DYO89599, Knob Naster State Park
Animal tunnel
Warrensburg, MO
O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65331	DYO No.: 89599	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D2 OF D9		



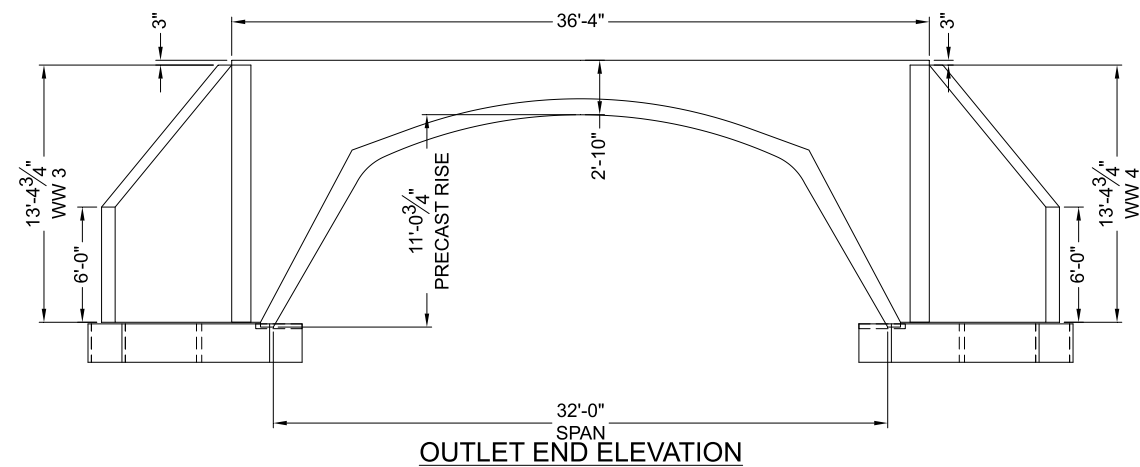
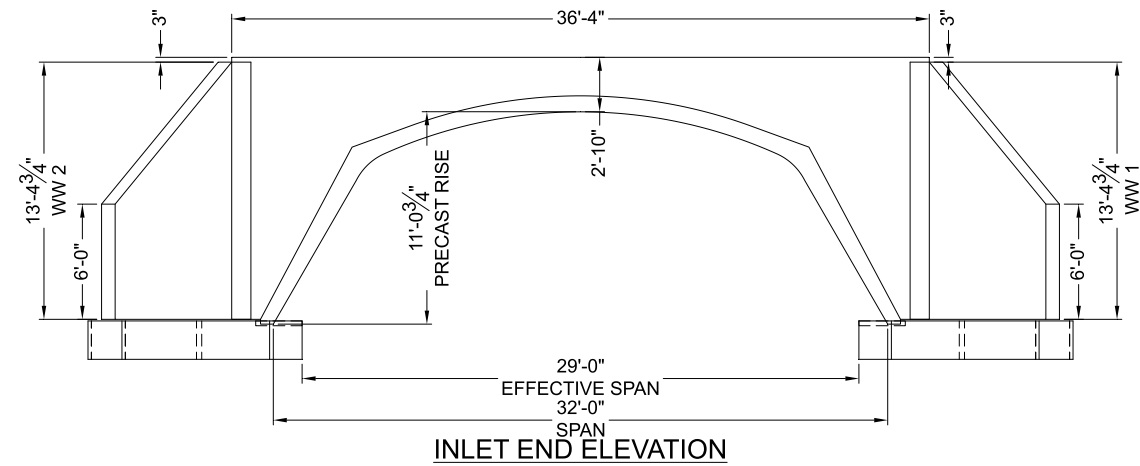
LONGITUDINAL SECTION



CROSS SECTION

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				SHEET NO.: D3 OF D9																	
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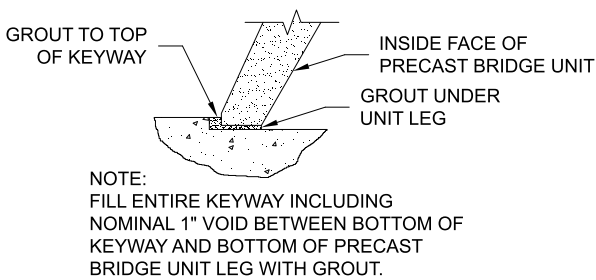
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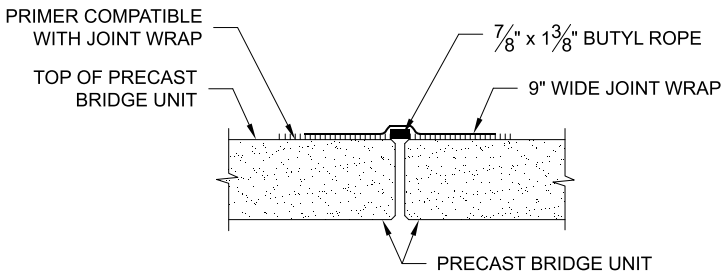
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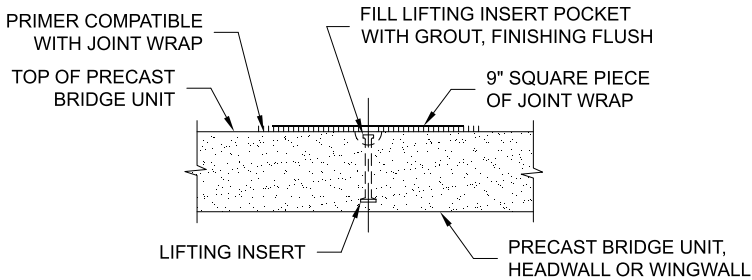
CONTECH ENGINEERED SOLUTIONS LLC www.ContechES.com 9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069 800-338-1122 513-645-7000 513-645-7993 FAX	CONSPAN O-SERIES DYOB DRAWING	DYO89599, Knob Naster State Park Animal tunnel Warrensburg, MO O Series, 32' Span x 11'-0 3/4" Rise	<table><tr><td>PROJECT No.: 65331</td><td>DYO No.: 89599</td><td>DATE: 10/21/2025</td></tr><tr><td>DESIGNED: DYO</td><td colspan="2">DRAWN: DYO</td></tr><tr><td>CHECKED: DYO</td><td colspan="2">APPROVED: DYO</td></tr><tr><td colspan="3">SHEET NO.: D4 OF D9</td></tr></table>	PROJECT No.: 65331	DYO No.: 89599	DATE: 10/21/2025	DESIGNED: DYO	DRAWN: DYO		CHECKED: DYO	APPROVED: DYO		SHEET NO.: D4 OF D9		
PROJECT No.: 65331	DYO No.: 89599	DATE: 10/21/2025													
DESIGNED: DYO	DRAWN: DYO														
CHECKED: DYO	APPROVED: DYO														
SHEET NO.: D4 OF D9															



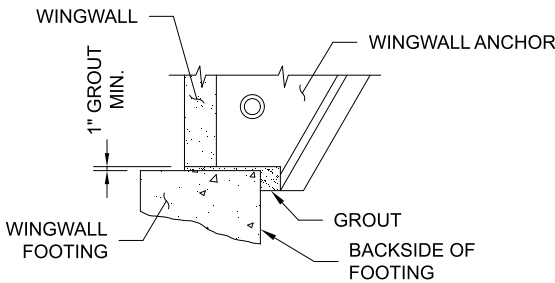
TYPICAL BRIDGE UNIT GROUT DETAIL
NOT TO SCALE



TYPICAL JOINT SEAL DETAIL
NOT TO SCALE

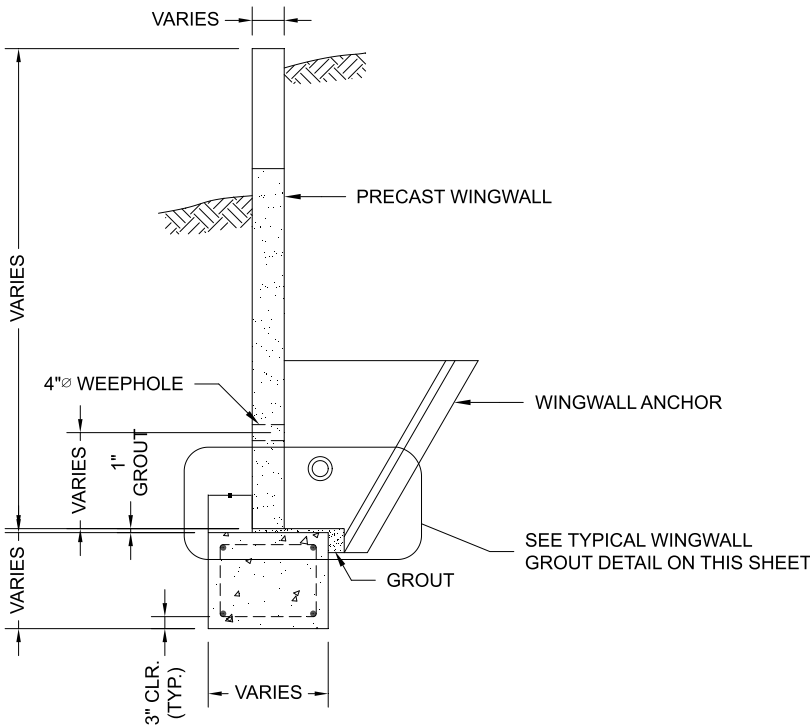


TYPICAL LIFT INSERT SEALING DETAIL
NOT TO SCALE



- NOTES:
- MINIMUM 1" GROUT UNDER WINGWALL LEG & ANCHOR STEM.
 - AREA BETWEEN WINGWALL FOOTING AND WINGWALL ANCHOR SHALL BE GROUTED SOLID BEFORE BACKFILL.
 - FORM BACKSIDE OF FOOTING TO DIMENSIONS SHOWN ON FOUNDATION PLAN.

TYPICAL WINGWALL GROUT DETAIL
NOT TO SCALE



TYPICAL WINGWALL SECTION
NOT TO SCALE

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CONSPAN

SERIES

DYOB
DRAWING

DYO89599, Knob Naster State Park
Animal tunnel
Warrensburg, MO
O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65331	DYO No.: 89599	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D5 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS

1. **DESCRIPTION**
- 1.1. TYPE - THIS WORK SHALL CONSIST OF FURNISHING AND CONSTRUCTING A CON/SPAN® O-SERIES BRIDGE SYSTEM IN ACCORDANCE WITH THESE SPECIFICATIONS AND IN REASONABLY CLOSE CONFORMITY WITH THE LINES, GRADES, DESIGN AND DIMENSIONS SHOWN ON THE PLANS OR AS ESTABLISHED BY THE ENGINEER. IN SITUATIONS WHERE TWO OR MORE SPECIFICATIONS APPLY TO THIS WORK, THE MOST STRINGENT REQUIREMENTS SHALL GOVERN.
- 1.2. DESIGNATION - PRECAST REINFORCED CONCRETE CON/SPAN® O-SERIES BRIDGE UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY SPAN AND RISE. PRECAST REINFORCED CONCRETE WINGWALLS AND HEADWALLS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT, AND DEFLECTION ANGLE. PRECAST REINFORCED CONCRETE EXPRESS™ FOUNDATION UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT AND WIDTH.
2. **DESIGN**
- 2.1. SPECIFICATIONS - THE PRECAST ELEMENTS ARE DESIGNED IN ACCORDANCE WITH THE "AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS" 8TH EDITION, ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2017. A MINIMUM OF ONE FOOT OF COVER ABOVE THE CROWN OF THE BRIDGE UNITS IS REQUIRED IN THE INSTALLED CONDITION. (UNLESS NOTED OTHERWISE ON THE SHOP DRAWINGS AND DESIGNED ACCORDINGLY.)
3. **MATERIALS**
- 3.1. CONCRETE - THE CONCRETE FOR THE PRECAST ELEMENTS SHALL BE AIR-ENTRAINED WHEN INSTALLED IN AREAS SUBJECT TO FREEZE-THAW CONDITIONS, COMPOSED OF PORTLAND CEMENT, FINE AND COARSE AGGREGATES, ADMIXTURES AND WATER. AIR-ENTRAINED CONCRETE SHALL CONTAIN 6 ± 2 PERCENT AIR. THE AIR-ENTRAINING ADMIXTURE SHALL CONFORM TO AASHTO M154. THE MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE AS SHOWN ON THE SHOP DRAWINGS.
- 3.1.1. PORTLAND CEMENT - SHALL CONFORM TO THE REQUIREMENTS OF ASTM SPECIFICATIONS C150-TYPE I, TYPE II, OR TYPE III CEMENT.
- 3.1.2. COARSE AGGREGATE - SHALL CONSIST OF STONE HAVING A MAXIMUM SIZE OF 1 INCH. AGGREGATE SHALL MEET REQUIREMENTS FOR ASTM C33.
- 3.1.3. WATER REDUCING ADMIXTURE - THE MANUFACTURER MAY SUBMIT, FOR APPROVAL BY THE ENGINEER, A WATER-REDUCING ADMIXTURE FOR THE PURPOSE OF INCREASING WORKABILITY AND REDUCING THE WATER REQUIREMENT FOR THE CONCRETE.
- 3.1.4. CALCIUM CHLORIDE - THE ADDITION TO THE MIX OF CALCIUM CHLORIDE OR ADMIXTURES CONTAINING CALCIUM CHLORIDE WILL NOT BE PERMITTED.
- 3.1.5. MIXTURE - THE AGGREGATES, CEMENT AND WATER SHALL BE PROPORTIONED AND MIXED IN A BATCH MIXER TO PRODUCE A HOMOGENEOUS CONCRETE MEETING THE STRENGTH REQUIREMENTS OF THIS SPECIFICATION. THE PROPORTION OF PORTLAND CEMENT IN THE MIXTURE SHALL NOT BE LESS THAN 564 POUNDS (6 SACKS) PER CUBIC YARD OF CONCRETE.
- 3.2. STEEL REINFORCEMENT
- 3.2.1. THE MINIMUM STEEL YIELD STRENGTH SHALL BE 60,000 PSI, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS.
- 3.2.2. ALL REINFORCING STEEL FOR THE PRECAST ELEMENTS SHALL BE FABRICATED AND PLACED IN ACCORDANCE WITH THE DETAILED SHOP DRAWINGS SUBMITTED BY THE MANUFACTURER.
- 3.2.3. REINFORCEMENT SHALL CONSIST OF WELDED WIRE REINFORCING CONFORMING TO ASTM SPECIFICATION A 1064, OR DEFORMED STEEL BARS CONFORMING TO ASTM SPECIFICATION A 615, GRADE 60. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY CONSIST OF WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS.
- 3.3. STEEL HARDWARE
- 3.3.1. BOLTS AND THREADED RODS FOR WINGWALL CONNECTIONS SHALL CONFORM TO ASTM A 307. NUTS SHALL CONFORM TO AASHTO M292 (ASTM A194) GRADE 2H. ALL BOLTS, THREADED RODS AND NUTS USED IN WINGWALL CONNECTIONS SHALL BE MECHANICALLY ZINC COATED IN ACCORDANCE WITH ASTM B695 CLASS 50.
- 3.3.2. STRUCTURAL STEEL FOR WINGWALL CONNECTION PLATES AND PLATE WASHERS SHALL CONFORM TO AASHTO M 270 (ASTM A 709) GRADE 36 AND SHALL BE HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).
- 3.3.3. INSERTS FOR WINGWALLS SHALL BE 1" DIAMETER TWO-BOLT PRESET WINGWALL ANCHORS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED IN ACCORDANCE WITH ASTM B633 SC-1.
- 3.3.4. FERRULE LOOP INSERTS SHALL BE F-64 FERRULE LOOP INSERTS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED.
- 3.3.5. HOOK BOLTS USED IN ATTACHED HEADWALL CONNECTIONS SHALL BE ASTM A307.
- 3.3.6. INSERTS FOR DETACHED HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL, EXPANDED COIL INSERTS AS MANUFACTURED BY DAYTON SUPERIOR

CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700. COIL RODS AND NUTS USED IN HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL. WASHERS USED IN HEADWALL CONNECTIONS SHALL BE EITHER AISI TYPE 304 STAINLESS STEEL PLATE WASHERS OR AASHTO M270 (ASTM A709) GRADE 36 PLATE WASHERS HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).

3.3.7. MECHANICAL SPLICES OF REINFORCING BARS SHALL BE MADE USING THE DOWEL BAR SPLICER SYSTEM AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700, AND SHALL CONSIST OF THE DBDI SPLICE SYSTEM (DOWEL BAR SPLICER AND DOWEL-IN), OR AS MANUFACTURED BY BARSPlice PRODUCTS INC, DAYTON, OHIO, (937)-275-8700, AND SHALL CONSIST OF BARSPLICER XP TYPE 2 SYSTEM.

4. **MANUFACTURE OF PRECAST ELEMENTS** - SUBJECT TO THE PROVISIONS OF SECTION 5, BELOW, THE PRECAST ELEMENT DIMENSION AND REINFORCEMENT DETAILS SHALL BE AS PRESCRIBED IN THE PLAN AND SHOP DRAWINGS PROVIDED BY THE MANUFACTURER.

- 4.1. FORMS - THE FORMS USED IN MANUFACTURE SHALL BE SUFFICIENTLY RIGID AND ACCURATE TO MAINTAIN THE REQUIRED PRECAST ELEMENT DIMENSIONS WITHIN THE PERMISSIBLE VARIATIONS GIVEN IN SECTION 5 OF THESE SPECIFICATIONS. ALL CASTING SURFACES SHALL BE OF A SMOOTH MATERIAL.

- 4.2. **PLACEMENT OF REINFORCEMENT**

4.2.1. **PLACEMENT OF REINFORCEMENT IN PRECAST BRIDGE UNITS** - THE COVER OF CONCRETE OVER THE OUTSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 2" MINIMUM. THE COVER OF CONCRETE OVER THE INSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 1½" MINIMUM, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS. THE CLEAR DISTANCE OF THE END CIRCUMFERENTIAL WIRES SHALL NOT BE LESS THAN 1" NOR MORE THAN 2" FROM THE ENDS OF EACH SECTION. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING SINGLE OR MULTIPLE LAYERS OF WELDED WIRE FABRIC (NOT TO EXCEED 3 LAYERS), SUPPLEMENTED WITH A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS, WHEN NECESSARY. WELDED WIRE FABRIC SHALL BE COMPOSED OF CIRCUMFERENTIAL AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE BRIDGE UNIT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW. THE ENDS OF THE LONGITUDINAL DISTRIBUTION REINFORCEMENT SHALL BE NOT MORE THAN 3" AND NOT LESS THAN 1½" FROM THE ENDS OF THE BRIDGE UNIT.

- 4.2.2. **BENDING OF REINFORCEMENT FOR PRECAST BRIDGE UNITS** - THE OUTSIDE AND INSIDE CIRCUMFERENTIAL REINFORCING STEEL FOR THE CORNERS OF THE BRIDGE SHALL BE BENT TO SUCH AN ANGLE THAT IS APPROXIMATELY EQUAL TO THE CONFIGURATION OF THE BRIDGE'S OUTSIDE CORNER.

4.2.3. **PLACEMENT OF REINFORCEMENT FOR PRECAST WINGWALLS AND HEADWALLS** - THE COVER OF CONCRETE OVER THE LONGITUDINAL AND TRANSVERSE REINFORCEMENT SHALL BE 2" MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 1½" NOR MORE THAN 3". REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC, OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.

4.2.4. **PLACEMENT OF REINFORCEMENT FOR PRECAST FOUNDATION UNITS** - THE COVER OF CONCRETE OVER THE BOTTOM REINFORCEMENT SHALL BE 3 INCHES MINIMUM. THE COVER OF CONCRETE FOR ALL OTHER REINFORCEMENT SHALL BE 2 INCHES MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 2 INCHES NOR MORE THAN 3 INCHES. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.

- 4.3. **LAPS, WELDS, SPACING**

4.3.1. **LAPS, WELDS, AND SPACING FOR PRECAST BRIDGE UNITS** - TENSION SPLICES IN THE CIRCUMFERENTIAL REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS

MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. THE OVERLAP OF WELDED WIRE FABRIC SHALL BE MEASURED BETWEEN THE OUTER-MOST LONGITUDINAL WIRES OF EACH FABRIC SHEET. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1 FOR SPLICES OTHER THAN TENSION SPLICES. THE OVERLAP SHALL BE A MINIMUM OF 1'-0" FOR WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS. THE SPACING CENTER TO CENTER OF THE CIRCUMFERENTIAL WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 4". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL WIRES SHALL NOT BE MORE THAN 8". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL DISTRIBUTION STEEL FOR EITHER LINE OF REINFORCING IN THE TOP SLAB SHALL BE NOT MORE THAN 1'-4".

4.3.2. **LAPS, WELDS, AND SPACING FOR PRECAST WINGWALLS, HEADWALLS AND FOUNDATIONS** - SPLICES IN THE REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1. THE SPACING CENTER-TO-CENTER OF THE WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 8".

- 4.4. **CURING** - THE PRECAST CONCRETE ELEMENTS SHALL BE CURED FOR A SUFFICIENT LENGTH OF TIME SO THAT THE CONCRETE WILL DEVELOP THE SPECIFIED COMPRESSIVE STRENGTH IN 28 DAYS OR LESS. ANY ONE OF THE FOLLOWING METHODS OF CURING OR COMBINATIONS THERE OF SHALL BE USED:

4.4.1. **STEAM CURING** - THE PRECAST ELEMENTS MAY BE LOW-PRESSURE STEAM CURED BY A SYSTEM THAT WILL MAINTAIN A MOIST ATMOSPHERE.

4.4.2. **WATER CURING** - THE PRECAST ELEMENTS MAY BE WATER CURED BY ANY METHOD THAT WILL KEEP THE SECTIONS MOIST.

4.4.3. **MEMBRANE CURING** - A SEALING MEMBRANE CONFORMING TO THE REQUIREMENTS OF ASTM SPECIFICATION C309 MAY BE APPLIED AND SHALL BE LEFT INTACT UNTIL THE REQUIRED CONCRETE COMPRESSIVE STRENGTH IS ATTAINED. THE CONCRETE TEMPERATURE AT THE TIME OF APPLICATION SHALL BE WITHIN +/- 10 DEGREES F OF THE ATMOSPHERIC TEMPERATURE. ALL SURFACES SHALL BE KEPT MOIST PRIOR TO THE APPLICATION OF THE COMPOUNDS AND SHALL BE DAMP WHEN THE COMPOUND IS APPLIED.

- 4.5. **STORAGE, HANDLING & DELIVERY**

4.5.1. **STORAGE** - PRECAST CONCRETE BRIDGE ELEMENTS SHALL BE LIFTED AND STORED IN "AS-CAST" POSITION. PRECAST CONCRETE HEADWALL AND WINGWALL UNITS ARE CAST, STORED AND SHIPPED IN A FLAT POSITION. THE PRECAST ELEMENTS SHALL BE STORED IN SUCH A MANNER TO PREVENT CRACKING OR DAMAGE. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE. THE UNITS SHALL NOT BE MOVED UNTIL THE CONCRETE COMPRESSIVE STRENGTH HAS REACHED A MINIMUM OF 2500 PSI (3000 PSI FOR SPANS >48 FEET), AND THEY SHALL NOT BE STORED IN AN UPRIGHT POSITION.

4.5.2. **HANDLING** - HANDLING DEVICES SHALL BE PERMITTED IN EACH PRECAST ELEMENT FOR THE PURPOSE OF HANDLING AND SETTING. SPREADER BEAMS MAY BE REQUIRED FOR THE LIFTING OF PRECAST CONCRETE BRIDGE ELEMENTS TO PRECLUDE DAMAGE FROM BENDING OR TORSION FORCES.

4.5.3. **DELIVERY** - PRECAST CONCRETE ELEMENTS MUST NOT BE SHIPPED UNTIL THE CONCRETE HAS ATTAINED THE SPECIFIED DESIGN COMPRESSIVE STRENGTH, OR AS DIRECTED BY THE DESIGN ENGINEER. PRECAST CONCRETE ELEMENTS MAY BE UNLOADED AND PLACED ON THE GROUND AT THE SITE UNTIL INSTALLED. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE.

- 4.6. **QUALITY ASSURANCE** - THE PRECASTER SHALL DEMONSTRATE ADHERENCE TO THE STANDARDS SET FORTH IN THE NPCA QUALITY CONTROL MANUAL. THE PRECASTER SHALL MEET EITHER SECTION 4.6.1 OR 4.6.2.

4.6.1. **CERTIFICATION** - THE PRECASTER SHALL BE CERTIFIED BY THE PRECAST/PRESTRESSED CONCRETE INSTITUTE PLANT CERTIFICATION PROGRAM OR THE NATIONAL PRECAST CONCRETE ASSOCIATION'S PLANT CERTIFICATION PROGRAM PRIOR TO AND DURING PRODUCTION OF THE PRODUCTS COVERED BY THIS SPECIFICATION.

- 4.6.2. **QUALIFICATIONS, TESTING AND INSPECTION**

4.6.2.1. THE PRECASTER SHALL HAVE BEEN IN THE BUSINESS OF PRODUCING PRECAST CONCRETE PRODUCTS SIMILAR TO THOSE SPECIFIED FOR A MINIMUM OF THREE YEARS. HE SHALL MAINTAIN A PERMANENT QUALITY CONTROL DEPARTMENT OR RETAIN AN INDEPENDENT TESTING AGENCY ON A CONTINUING BASIS. THE AGENCY SHALL ISSUE A REPORT, CERTIFIED BY A LICENSED ENGINEER, DETAILING THE ABILITY OF THE PRECASTER TO PRODUCE QUALITY PRODUCTS CONSISTENT WITH INDUSTRY STANDARDS.

4.6.2.2. THE PRECASTER SHALL SHOW THAT THE

FOLLOWING TESTS ARE PERFORMED IN ACCORDANCE WITH THE ASTM STANDARDS INDICATED. TESTS SHALL BE PERFORMED AS INDICATED IN SECTION 6 OF THESE SPECIFICATIONS.

4.6.2.2.1. AIR CONTENT: C231 OR C173

4.6.2.2.2. COMPRESSIVE STRENGTH: C31,C39,C497

4.6.2.3. THE PRECASTER SHALL PROVIDE DOCUMENTATION DEMONSTRATING COMPLIANCE WITH THIS SECTION TO CONTECH® ENGINEERED SOLUTIONS AT REGULAR INTERVALS OR UPON REQUEST.

4.6.2.4. THE OWNER MAY PLACE AN INSPECTOR IN THE PLANT WHEN THE PRODUCTS COVERED BY THIS SPECIFICATION ARE BEING MANUFACTURED.

4.6.3. **DOCUMENTATION** - THE PRECASTER SHALL SUBMIT PRECAST PRODUCTION REPORTS TO CONTECH® ENGINEERED SOLUTIONS AS REQUIRED.

5. **PERMISSIBLE VARIATIONS**

- 5.1. **BRIDGE UNITS**

5.1.1. **INTERNAL DIMENSIONS** - THE INTERNAL DIMENSION SHALL VARY NOT MORE THAN 1% FROM THE DESIGN DIMENSIONS NOR MORE THAN 1½" WHICHEVER IS LESS.

5.1.2. **SLAB AND WALL THICKNESS** - THE SLAB AND WALL THICKNESS SHALL NOT BE LESS THAN THAT SHOWN IN THE DESIGN BY MORE THAN ½". A THICKNESS MORE THAN THAT REQUIRED IN THE DESIGN SHALL NOT BE CAUSE FOR REJECTION.

5.1.3. **LENGTH OF OPPOSITE SURFACES** - VARIATIONS IN LAYING LENGTHS OF TWO OPPOSITE SURFACES OF THE BRIDGE UNIT SHALL NOT BE MORE THAN ½" IN ANY SECTION, EXCEPT WHERE BEVELED ENDS FOR LAYING OF CURVES ARE SPECIFIED BY THE PURCHASER.

5.1.4. **LENGTH OF SECTION** - THE UNDERRUN IN LENGTH OF A SECTION SHALL NOT BE MORE THAN ½" IN ANY BRIDGE UNIT.

5.1.5. **POSITION OF REINFORCEMENT** - THE MAXIMUM VARIATION IN POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½" FOR THE OUTSIDE CIRCUMFERENTIAL STEEL OR BE LESS THAN 1" FOR THE INSIDE CIRCUMFERENTIAL STEEL AS MEASURED TO THE EXTERNAL OR INTERNAL SURFACE OF THE BRIDGE. THESE TOLERANCES OR COVER REQUIREMENTS DO NOT APPLY TO MATING SURFACES OF THE JOINTS.

5.1.6. **AREA OF REINFORCEMENT** - THE AREAS OF STEEL REINFORCEMENT SHALL BE THE DESIGN STEEL AREAS AS SHOWN IN THE MANUFACTURER'S SHOP DRAWINGS. STEEL AREAS GREATER THAN THOSE REQUIRED SHALL NOT BE CAUSE FOR REJECTION. THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCEMENT SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCEMENT.

- 5.2. **WINGWALLS & HEADWALLS**

5.2.1. **WALL THICKNESS** - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".

5.2.2. **LENGTH/HEIGHT OF WALL SECTIONS** - THE LENGTH AND HEIGHT OF THE WALL SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".

5.2.3. **POSITION OF REINFORCEMENT** - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".

5.2.4. **SIZE OF REINFORCEMENT** - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.

- 5.3. **FOUNDATION UNITS**

5.3.1. **WALL THICKNESS** - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".

5.3.2. **LENGTH/HEIGHT/WIDTH OF FOUNDATION SECTIONS** - THE LENGTH, HEIGHT AND WIDTH OF THE FOUNDATION UNITS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".

5.3.3. **POSITION OF REINFORCEMENT** - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".

5.3.4. **SIZE OF REINFORCEMENT** - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.

6. **TESTING/ INSPECTION**

- 6.1. **TESTING**

6.1.1. **TYPE OF TEST SPECIMEN** - CONCRETE COMPRESSIVE STRENGTH SHALL BE DETERMINED FROM COMPRESSION TESTS MADE ON CYLINDERS OR CORES. FOR CYLINDER TESTING, A MINIMUM OF 4 CYLINDERS SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. FOR CORE TESTING, A MINIMUM OF 2 CORES SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. EACH ELEMENT SHALL BE CONSIDERED SEPARATELY FOR THE PURPOSE OF TESTING AND ACCEPTANCE.

6.1.2. **COMPRESSION TESTING** - CYLINDERS SHALL BE MADE AND TESTED AS PRESCRIBED BY THE ASTM C39 SPECIFICATION. CYLINDERS SHALL BE CURED IN THE SAME ENVIRONMENT AS THE BRIDGE ELEMENTS. CORES SHALL BE OBTAINED AND TESTED FOR COMPRESSIVE STRENGTH FROM EACH ELEMENT IN ACCORDANCE WITH THE PROVISIONS OF THE

ASTM C42 SPECIFICATION.

6.1.3. **ACCEPTABILITY OF CYLINDER TESTS** - WHEN THE AVERAGE COMPRESSIVE STRENGTH OF ALL CYLINDERS TESTED IS EQUAL TO OR GREATER THAN THE DESIGN COMPRESSIVE STRENGTH, AND NOT MORE THAN 10% OF THE CYLINDERS TESTED HAVE A COMPRESSIVE STRENGTH LESS THAN THE DESIGN CONCRETE STRENGTH, AND NO CYLINDER TESTED HAS A COMPRESSIVE STRENGTH LESS THAN 90% OF THE REQUIRED CONCRETE STRENGTH, THEN THE ELEMENT SHALL BE ACCEPTED. WHEN THE COMPRESSIVE STRENGTH OF THE CYLINDERS TESTED DOES NOT CONFORM TO THESE ACCEPTANCE CRITERIA, THE ACCEPTABILITY OF THE ELEMENT MAY BE DETERMINED AS DESCRIBED IN SECTION 6.1.4, BELOW.

6.1.4. **ACCEPTABILITY OF CORE TESTS** - THE COMPRESSIVE STRENGTH OF THE CONCRETE IN A BRIDGE ELEMENT IS ACCEPTABLE WHEN EACH CORE TEST STRENGTH IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH. WHEN THE COMPRESSIVE STRENGTH OF A CORE TESTED IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN MAY BE RE-CORED. WHEN THE COMPRESSIVE STRENGTH OF THE RE-CORE IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH, THE COMPRESSIVE STRENGTH OF THE CONCRETE IN THAT BRIDGE ELEMENT IS ACCEPTABLE.

6.1.4.1. WHEN THE COMPRESSIVE STRENGTH OF ANY

RECORE IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN SHALL BE REJECTED.

6.1.4.2. **PLUGGING CORE HOLES** - THE CORE HOLES SHALL BE PLUGGED AND SEALED BY THE MANUFACTURER IN A MANNER SUCH THAT THE ELEMENTS WILL MEET ALL OF THE TEST REQUIREMENTS OF THIS SPECIFICATION. PRECAST ELEMENTS SO SEALED SHALL BE CONSIDERED SATISFACTORY FOR USE.

6.1.4.3. **TEST EQUIPMENT** - EVERY MANUFACTURER FURNISHING PRECAST ELEMENTS UNDER THIS SPECIFICATION SHALL FURNISH ALL FACILITIES AND PERSONNEL NECESSARY TO CARRY OUT THE TEST REQUIRED.

6.2. **INSPECTION** - THE QUALITY OF MATERIALS, THE PROCESS OF MANUFACTURE, AND THE FINISHED PRECAST ELEMENTS SHALL BE SUBJECT TO INSPECTION BY THE PURCHASER.

7. **JOINTS**

THE BRIDGE UNITS SHALL BE PRODUCED WITH FLAT BUTT ENDS. THE ENDS OF THE BRIDGE UNITS SHALL BE SUCH THAT WHEN THE SECTIONS ARE LAID TOGETHER THEY WILL MAKE A CONTINUOUS LINE WITH A SMOOTH INTERIOR FREE OF APPRECIABLE IRREGULARITIES, ALL COMPATIBLE WITH THE PERMISSIBLE VARIATIONS IN SECTION 5, ABOVE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED ½".

8. **WORKMANSHIP/ FINISH**

THE BRIDGE UNITS, WINGWALLS, HEADWALLS AND FOUNDATION UNITS SHALL BE SUBSTANTIALLY FREE OF FRACTURES. THE ENDS OF THE BRIDGE UNITS SHALL BE NORMAL TO THE WALLS AND CENTERLINE OF THE BRIDGE SECTION, WITHIN THE LIMITS OF THE VARIATIONS GIVEN IN SECTION 5, ABOVE, EXCEPT WHERE BEVELED ENDS ARE SPECIFIED. THE FACES OF THE WINGWALLS AND HEADWALLS SHALL BE PARALLEL TO EACH OTHER, WITHIN THE LIMITS OF VARIATIONS GIVEN IN SECTION 5, ABOVE. THE SURFACE OF THE PRECAST ELEMENTS SHALL BE A SMOOTH STEEL FORM OR TROWELED SURFACE. TRAPPED AIR POCKETS CAUSING SURFACE DEFECTS SHALL BE CONSIDERED AS PART OF A SMOOTH, STEEL FORM FINISH.

9. **REPAIRS**

PRECAST ELEMENTS MAY BE REPAIRED, IF NECESSARY, BECAUSE OF IMPERFECTIONS IN MANUFACTURE OR HANDLING DAMAGE AND WILL BE ACCEPTABLE IF, IN THE OPINION OF THE PURCHASER, THE REPAIRS ARE SOUND, PROPERLY FINISHED AND CURED, AND THE REPAIRED SECTION CONFORMS TO THE REQUIREMENTS OF THIS SPECIFICATION.

10. **REJECTION**

THE PRECAST ELEMENTS SHALL BE SUBJECT TO REJECTION ON ACCOUNT OF ANY OF THE SPECIFICATION REQUIREMENTS. INDIVIDUAL PRECAST ELEMENTS MAY BE REJECTED BECAUSE OF ANY OF THE FOLLOWING:

10.1. FRACTURES OR CRACKS PASSING THROUGH THE WALL, EXCEPT FOR A SINGLE END CRACK THAT DOES NOT EXCEED ONE HALF THE THICKNESS OF THE WALL.

10.2. DEFECTS THAT INDICATE PROPORTIONING, MIXING, AND MOLDING NOT IN COMPLIANCE WITH SECTION 4 OF THESE SPECIFICATIONS.

10.3. HONEYCOMBED OR OPEN TEXTURE.

10.4. DAMAGED ENDS, WHERE SUCH DAMAGE WOULD PREVENT MAKING A SATISFACTORY JOINT.

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DYOB
DRAWING

CON/SPAN O-SERIES
SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.:		
D6 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS (CONT'D)

11. **MARKING**
EACH BRIDGE UNIT SHALL BE CLEARLY MARKED BY WATERPROOF PAINT. THE FOLLOWING SHALL BE SHOWN ON THE INSIDE OF THE VERTICAL LEG OF THE BRIDGE SECTION:
BRIDGE SPAN X BRIDGE RISE
DATE OF MANUFACTURE
NAME OR TRADEMARK OF THE MANUFACTURER

12. **INSTALLATION PREPARATION**
TO ENSURE CORRECT INSTALLATION OF THE PRECAST CONCRETE BRIDGE SYSTEM, CARE AND CAUTION MUST BE EXERCISED IN FORMING THE SUPPORT AREAS FOR BRIDGE UNITS, HEADWALL, AND WINGWALL ELEMENTS. EXERCISING SPECIAL CARE WILL FACILITATE THE RAPID INSTALLATION OF THE PRECAST COMPONENTS.

- 12.1. **FOOTINGS**
DO NOT OVER EXCAVATE FOUNDATIONS UNLESS DIRECTED BY SITE SOIL ENGINEER TO REMOVE UNSUITABLE SOIL.

THE SITE SOILS ENGINEER SHALL CERTIFY THAT THE BEARING CAPACITY MEETS OR EXCEEDS THE FOOTING DESIGN REQUIREMENTS, PRIOR TO THE CONTRACTOR POURING OF THE FOOTINGS.

THE BRIDGE UNITS AND WINGWALLS SHALL BE INSTALLED ON EITHER PRECAST OR CAST-IN-PLACE CONCRETE FOOTINGS. THE SIZE AND ELEVATION OF THE FOOTINGS SHALL BE AS DESIGNED BY THE ENGINEER. A KEYWAY SHALL BE FORMED IN THE TOP SURFACE OF THE BRIDGE FOOTING AS SPECIFIED ON THE PLANS. NO KEYWAY IS REQUIRED IN THE WINGWALL FOOTINGS, UNLESS OTHERWISE SPECIFIED ON THE PLANS.

THE FOOTINGS SHALL BE GIVEN A SMOOTH FLOAT FINISH AND SHALL REACH A COMPRESSIVE STRENGTH OF 2,000 PSI BEFORE PLACEMENT OF THE BRIDGE AND WINGWALL ELEMENTS. BACKFILLING SHALL NOT BEGIN UNTIL THE FOOTING HAS REACHED THE FULL DESIGN COMPRESSIVE STRENGTH.

THE FOOTING SURFACE SHALL BE CONSTRUCTED IN ACCORDANCE WITH GRADES SHOWN ON THE PLANS. WHEN TESTED WITH A 10'-0" STRAIGHT EDGE, THE SURFACE SHALL NOT VARY MORE THAN 1/4" IN 10'-0".

IF A PRECAST CONCRETE FOOTING IS USED, THE CONTRACTOR SHALL PREPARE A 4" THICK BASE LAYER OF COMPACTED GRANULAR MATERIAL THE FULL WIDTH OF THE FOOTING PRIOR TO PLACING THE PRECAST FOOTING.

THE FOUNDATIONS FOR PRECAST CONCRETE BRIDGE ELEMENTS AND WINGWALLS MUST BE CONNECTED BY REINFORCEMENT TO FORM ONE MONOLITHIC BODY. EXPANSION JOINTS SHALL NOT BE USED.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE CONSTRUCTION OF THE FOUNDATIONS PER THE PLANS AND SPECIFICATIONS.

13. **INSTALLATION**
13.1. **GENERAL** - THE INSTALLATION OF THE PRECAST CONCRETE ELEMENTS SHALL BE AS EXPLAINED IN THE PUBLICATION CON/SPAN BRIDGE SYSTEMS INSTALLATION HANDBOOK.

- 13.1.1. **LIFTING** - IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO ENSURE THAT A CRANE OF THE CORRECT LIFTING CAPACITY IS AVAILABLE TO HANDLE THE PRECAST CONCRETE UNITS. THIS CAN BE ACCOMPLISHED BY USING THE WEIGHTS GIVEN FOR THE PRECAST CONCRETE COMPONENTS AND BY DETERMINING THE LIFTING REACH FOR EACH CRANE UNIT. SITE CONDITIONS MUST BE CHECKED WELL IN ADVANCE OF SHIPPING TO ENSURE PROPER CRANE LOCATION AND TO AVOID ANY LIFTING RESTRICTIONS. THE LIFT ANCHORS OR HOLES PROVIDED IN EACH UNIT ARE THE ONLY MEANS TO BE USED TO LIFT THE ELEMENTS. THE PRECAST CONCRETE ELEMENTS MUST NOT BE SUPPORTED OR RAISED BY OTHER MEANS THAN THOSE GIVEN IN THE MANUALS AND DRAWINGS WITHOUT WRITTEN APPROVAL FROM CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2. **CONSTRUCTION EQUIPMENT WEIGHT RESTRICTIONS** - IN NO CASE SHALL EQUIPMENT OPERATING IN EXCESS OF THE DESIGN LOAD (HL-93) BE PERMITTED OVER THE BRIDGE UNITS UNLESS APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2.1. IN THE IMMEDIATE AREA OF THE BRIDGE UNITS, THE FOLLOWING RESTRICTIONS FOR THE USE OF HEAVY CONSTRUCTION MACHINERY DURING BACKFILLING OPERATIONS APPLY:

- NO CONSTRUCTION EQUIPMENT SHALL CROSS THE BARE PRECAST CONCRETE BRIDGE UNIT.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 4" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 10 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 1'-0" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 30 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED THE DESIGN COVER, OR 2'-0" MINIMUM, OVER THE CROWN OF THE PRECAST CONCRETE BRIDGE, CONSTRUCTION EQUIPMENT WITHIN THE DESIGN LOAD LIMITS FOR THE ROAD MAY CROSS THE PRECAST CONCRETE BRIDGE.

- 13.2. **LEVELING PAD/SHIMS** - THE BRIDGE UNITS AND WINGWALLS SHALL BE SET ON HARDBOARD SHIMS CONFORMING TO ASTM D1037 OR PLASTIC SHIMS (DAYTON SUPERIOR P-80, P-81 OR APPROVED EQUAL) MEASURING 5" x 5", MINIMUM, UNLESS SHOWN OTHERWISE ON THE PLANS. A MINIMUM GAP OF 1/2" SHALL BE PROVIDED BETWEEN THE FOOTING AND THE BOTTOM OF THE BRIDGE'S

VERTICAL LEGS OR THE BOTTOM OF THE WINGWALL. ALSO, A SUPPLY OF 1/4", 1/2" AND 3/8" THICK HARDBOARD OR PLASTIC SHIMS FOR VARIOUS SHIMMING PURPOSES SHALL BE ON SITE.

- 13.3. **PLACEMENT OF BRIDGE UNITS** - THE BRIDGE UNITS SHALL BE PLACED AS SHOWN ON THE ENGINEER'S PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED 1/4".

- 13.4. IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN THE STRUCTURE SPAN DURING ALL PHASES OF INSTALLATION. DUE TO THE ARCH SHAPE, BRIDGE ELEMENTS WILL TEND TO SPREAD UNDER SELF-WEIGHT. IT IS IMPERATIVE THAT ANY LATERAL SPREADING OF THE BRIDGE ELEMENTS BE AVOIDED DURING AND AFTER THEIR PLACEMENT. GENERALLY, HORIZONTAL CABLE TIES OR TIE RODS ARE SHIPPED IN THE LARGER BRIDGE ELEMENTS TO ASSIST IN PREVENTING THIS SPREADING. CABLE TIES/TIE RODS SHALL NOT BE REMOVED UNTILL BRIDGE UNITS ARE GROUTED AND GROUT HAS CURED. IT IS RECOMMENDED THAT TEMPORARY HARDWOOD BLOCKS BE USED IN CONJUNCTION WITH THE CABLE TIES/TIE RODS TO MAINTAIN SPAN. IF, HOWEVER, DUE TO SITE RESTRICTIONS, THESE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO PLACEMENT OF THE BRIDGE ELEMANTS, THE CONTRACTOR MUST NOTIFY CONTECH (MANUFACTURER) AND REQUEST A SUGGESTED INSTALLATION PROCEDURE.

IN ADDITION, IF THE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO SETTING ARCH UNITS, THE FOLLOWING QUALITY CONTROL PROCEDURE MUST BE FOLLOWED:

- 1) FIND "MEASURED SPAN" UPON ARCH UNIT'S DELIVERY TO SITE, PRIOR TO LIFTING FROM TRUCK AND REMOVING CABLE TIES/TIE RODS. "MEASURED SPAN" SHALL BE THE AVERAGE OF (3) SPAN MEASUREMENTS ALONG THE LAY LENGTH OF THE ARCH UNIT.
- 2) AFTER SETTING OF BRIDGE UNIT ON THE FOUNDATION, VERIFY THE SPAN. THIS "INSTALLED SPAN MEASUREMENT" SHALL NOT EXCEED THE MAXIMUM OF:
A) THE NOMINAL SPAN + 1/4" OR
B) THE "MEASURED SPAN"

IF THE "INSTALLED SPAN MEASUREMENT" EXCEEDS THIS AMOUNT, THE ARCH UNIT SHALL BE LIFTED AND RE-SET UNTIL THE "INSTALLED SPAN MEASUREMENT" MEETS THE LIMITS.

- 13.5. **PLACEMENT OF WINGWALLS, HEADWALLS AND FOUNDATION UNITS** - THE WINGWALLS, HEADWALLS AND FOUNDATIONS SHALL BE PLACED AS SHOWN ON THE PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE.

- 13.6. **JOINT PROTECTION AND SUBSURFACE DRAINAGE**

- 13.6.1. **EXTERNAL PROTECTION OF JOINTS** - THE BUTT JOINT MADE BY TWO ADJOINING BRIDGE UNITS SHALL BE COVERED WITH A 7/8" x 1 1/2" PREFORMED BITUMINOUS JOINT SEALANT AND A MINIMUM OF A 9" WIDE JOINT WRAP. THE SURFACE SHALL BE FREE OF DIRT BEFORE APPLYING THE JOINT MATERIAL. A PRIMER COMPATIBLE WITH THE JOINT WRAP TO BE USED SHALL BE APPLIED FOR A MINIMUM WIDTH OF 9" ON EACH SIDE OF THE JOINT. THE EXTERNAL WRAP SHALL BE CS212 BY CONCRETE SEALANTS INC., EZ-WRAP RUBBER BY PRESS-SEAL GASKET CORPORATION, SEAL WRAP BY MAR MAC MANUFACTURING CO. INC. OR APPROVED EQUAL. THE JOINT SHALL BE COVERED CONTINUOUSLY FROM THE BOTTOM OF ONE BRIDGE SECTION LEG, ACROSS THE TOP OF THE BRIDGE AND TO THE OPPOSITE BRIDGE SECTION LEG. ANY LAPS THAT RESULT IN THE JOINT WRAP SHALL BE A MINIMUM OF 6" LONG WITH THE OVERLAP RUNNING DOWNHILL.

- 13.6.2. **IN ADDITION TO THE JOINTS BETWEEN BRIDGE UNITS, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE HEADWALL SHALL ALSO BE SEALED AS DESCRIBED ABOVE. IF PRECAST WINGWALLS ARE USED, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE WINGWALL SHALL BE SEALED WITH A 2'-0" STRIP OF FILTER FABRIC. ALSO, IF LIFT HOLES ARE FORMED IN THE BRIDGE UNITS, THEY SHALL BE PRIMED AND COVERED WITH A 9" x 9" SQUARE OF JOINT WRAP.**

- 13.6.3. **DURING THE BACKFILLING OPERATION, CARE SHALL BE TAKEN TO KEEP THE JOINT WRAP IN ITS PROPER LOCATION OVER THE JOINT.**

- 13.6.4. **SUBSOIL DRAINAGE SHALL BE AS DIRECTED BY THE ENGINEER.**

- 13.7. **GROUTING**

- 13.7.1. **GROUTING SHALL NOT BE PERFORMED WHEN TEMPERATURES ARE EXPECTED TO GO BELOW 35° FOR A PERIOD OF 72 HOURS. GROUTING SHOULD BE COMPLETED AS SOON AS PRACTICAL AFTER PRECAST ARCHES HAVE BEEN INSTALLED. FILL THE BRIDGE-FOUNDATION KEYWAY WITH CEMENT GROUT (PORTLAND CEMENT AND WATER OR CEMENT MORTAR COMPOSED OF PORTLAND CEMENT, SAND AND WATER) WITH A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 3000 PSI. VIBRATE AS REQUIRED TO ENSURE THAT THE ENTIRE KEY AROUND THE BRIDGE ELEMENT IS COMPLETELY FILLED. IF BRIDGE ELEMENTS HAVE BEEN SET WITH TEMPORARY TIES (CABLES, BARS, ETC.) GROUT MUST ATTAIN A MINIMUM COMPRESSIVE STRENGTH OF 1500 PSI BEFORE TIES MAY BE REMOVED.**

- 13.7.2. **ALL GROUT SHALL HAVE A MAXIMUM AGGREGATE SIZE OF 1/4".**

- 13.7.3. **LIFTING AND ERECTION ANCHOR RECESSES SHALL BE FILLED WITH GROUT.**

- 13.7.4. **AFTER GROUT HAS REACHED ITS DESIGN STRENGTH THE TEMPORARY HARDWOOD WEDGES SHALL BE REMOVED AND THEIR HOLES FILLED WITH GROUT.**

- 13.8. **BACKFILL**

- 13.8.1. **DO NOT PERFORM BACKFILLING DURING WET OR FREEZING**

WEATHER.
13.8.2. **NO BACKFILL SHALL BE PLACED AGAINST ANY STRUCTURAL ELEMENTS UNTIL THEY HAVE BEEN APPROVED BY THE ENGINEER.**

- 13.8.3. **BACKFILL SHALL BE CONSIDERED AS ALL REPLACED EXCAVATION AND NEW EMBANKMENT ADJACENT TO THE PRECAST CONCRETE ELEMENTS. THE PROJECT CONSTRUCTION AND MATERIAL SPECIFICATIONS, WHICH INCLUDE THE SPECIFICATIONS FOR EXCAVATION FOR STRUCTURES AND ROADWAY EXCAVATION AND EMBANKMENT CONSTRUCTION, SHALL APPLY EXCEPT AS MODIFIED IN THIS SECTION.**

- 13.8.4. **BACKFILL ZONES:**

- IN-SITU SOIL
- ZONE A: CONSTRUCTED EMBANKMENT OR OVERFILL.
- ZONE B: FILL THAT IS DIRECTLY ASSOCIATED WITH PRECAST CONCRETE BRIDGE INSTALLATION.
- ZONE C: ROAD STRUCTURE.

- 13.8.5. **REQUIRED BACKFILL PROPERTIES**

- 13.8.5.1. **IN-SITU SOIL** - NATURAL GROUND IS TO BE SUFFICIENTLY STABLE TO ALLOW EFFECTIVE SUPPORT TO THE PRECAST CONCRETE BRIDGE UNITS. AS A GUIDE, THE EXISTING NATURAL GROUND SHOULD BE OF SIMILAR QUALITY AND DENSITY TO ZONE B MATERIAL FOR MINIMUM LATERAL DIMENSION OF ONE BRIDGE SPAN OUTSIDE OF THE BRIDGE FOOTING.

- 13.8.5.2. **ZONE A - ZONE A REQUIRES FILL MATERIAL WITH SPECIFICATIONS AND COMPACTING PROCEDURES EQUAL TO THAT FOR NORMAL ROAD EMBANKMENTS.**

- 13.8.5.3. **ZONE B - GENERALLY, SOILS SHALL BE REASONABLY FREE OF ORGANIC MATTER, AND, NEAR CONCRETE SURFACES, FREE OF STONES LARGER THAN 3" IN DIAMETER SEE CHARTS FOR DETAILED DESCRIPTIONS OF ACCEPTABLE SOILS.**

- 13.8.5.4. **ZONE C - ZONE C IS THE ROAD SECTION OF GRAVEL, ASPHALT OR CONCRETE BUILT IN COMPLIANCE WITH LOCAL ENGINEERING PRACTICES.**

- 13.8.5.5. **GEOTECHNICAL ENGINEER SHALL REVIEW GRADATIONS OF ALL INTERFACING MATERIALS AND, IF NECESSARY, RECOMMEND GEOTEXTILE FILTER FABRIC (PROVIDED BY CONTRACTOR)**

- 13.8.6. **PLACING AND COMPACTING BACKFILL**
DUMPING FOR BACKFILLING IS NOT ALLOWED ANY NEARER THAN 3'-0" FROM THE BRIDGE LEG.

THE FILL MUST BE PLACED AND COMPACTED IN LAYERS NOT EXCEEDING 8". THE MAXIMUM DIFFERENCE IN THE SURFACE LEVELS OF THE FILL ON OPPOSITE SIDES OF THE BRIDGE MUST NOT EXCEED 2'-0".

THE FILL BEHIND WINGWALLS MUST BE PLACED AT THE SAME TIME AS THAT OF THE BRIDGE FILL. IT MUST BE PLACED IN PROGRESSIVELY PLACED HORIZONTAL LAYERS NOT EXCEEDING 8" PER LAYER.

THE BACKFILL OF ZONE B SHALL BE COMPACTED TO A MINIMUM DENSITY OF 95% OF THE STANDARD PROCTOR, AS REQUIRED BY AASHTO T-99.

SOIL WITHIN 1'-0" OF CONCRETE SURFACES SHALL BE HAND-COMPACTED. ELSEWHERE, USE OF ROLLERS IS ACCEPTABLE. IF VIBRATING ROLLER-COMPACTORS ARE USED, THEY SHALL NOT BE STARTED OR STOPPED WITHIN ZONE B AND THE VIBRATION FREQUENCY SHOULD BE AT LEAST 30 REVOLUTIONS PER SECOND.

THE BACKFILL MATERIAL AND COMPACTING BEHIND WINGWALLS SHALL SATISFY THE CRITERIA FOR THE BRIDGE BACKFILL, ZONE B.

BACKFILL AGAINST A WATERPROOFED SURFACE SHALL BE PLACED CAREFULLY TO AVOID DAMAGE TO THE WATERPROOFING MATERIAL.

- 13.8.7. **BRIDGE UNITS**
FOR FILL HEIGHTS OVER 12 FEET (AS MEASURED FROM TOP CROWN OF BRIDGE TO FINISHED GRADE), NO BACKFILLING MAY BEGIN UNTIL A BACKFILL COMPACTION TESTING PLAN HAS BEEN COORDINATED WITH AND APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

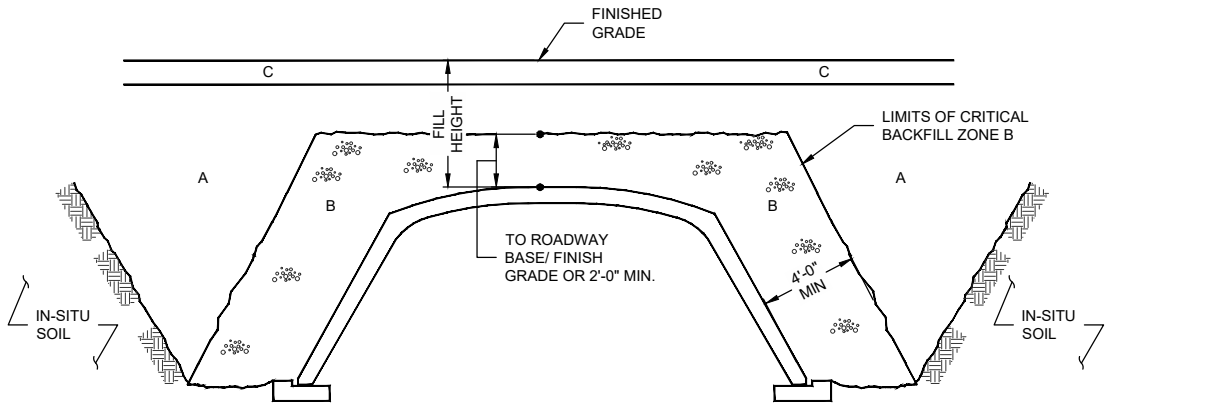
- 13.8.8. **WINGWALLS**
BACKFILL IN FRONT OF WINGWALLS SHALL BE CARRIED TO GROUND LINES SHOWN IN THE PLANS.

- 13.8.9. **MONITORING**
THE CONTRACTOR SHALL CHECK SETTLEMENTS AND HORIZONTAL DISPLACEMENT OF FOUNDATION TO ENSURE THAT THEY ARE WITHIN THE ALLOWABLE LIMIT PROVIDED BY THE ENGINEER. THESE MEASUREMENTS SHOULD GIVE AN INDICATION OF THE SETTLEMENTS AND DEFORMATIONS ALONG THE LENGTH OF THE FOUNDATIONS.

THE FIRST MEASUREMENT SHOULD TAKE PLACE AFTER THE ERECTION OF ALL PRECAST BRIDGE SYSTEM ELEMENTS, A SECOND AFTER COMPLETION OF BACKFILLING, AND A THIRD BEFORE OPENING OF THE BRIDGE TO TRAFFIC. FURTHER MEASUREMENTS MAY BE MADE ACCORDING TO LOCAL CONDITIONS.

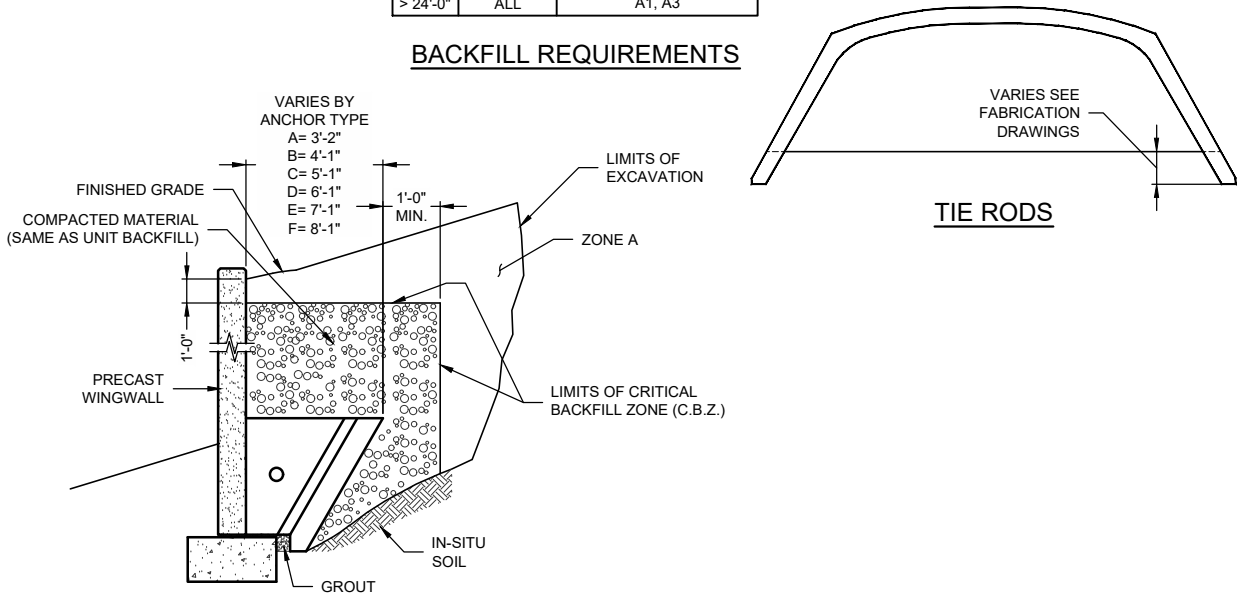
ACCEPTABLE SOILS FOR USE IN ZONE B BACKFILL

TYPICAL USCS MATERIALS	AASHTO GROUP	AASHTO SUBGROUP	PERCENT PASSING US SIEVE NO.			CHARACTER OF FRACTION PASSING NO. 40 SIEVE		SOIL DESRIPTION
			#10	#40	#200	LIQUID LIMIT	PLASTICITY INDEX	
GW, GP, SP	A1	A-1a	50 MAX	30 MAX	15 MAX	6 MAX		LARGELY GRAVEL BUT CAN INCLUDE SAND AND FINES GRAVELLY SAND OR GRADED SAND, MAY INCLUDE FINES
GM, SW, SP, SM		A-1b		50 MAX	25 MAX	6 MAX		
GM, SM, ML, SP, GP	A2	A-2-4			35 MAX	40 MAX	10 MAX	SANDS, GRAVELS WITH LOW- PLASTICITY SILT FINES SANDS, GRAVELS WITH PLASTIC SILT FINES
SC, GC, GM		A-2-5			35 MAX	41 MIN	10 MAX	
SP, SM, SW	A3			51 MIN	10 MAX	NON- PLASTIC		FINE SANDS
ML, SM, SC	A4				36 MIN	40 MAX	10 MAX	LOW-COMPRESSIBLTY SILTS



SPAN	FILL HEIGHT	ACCEPTABLE MATERIAL INSIDE ZONE B
≤ 24'-0"	≥ 12'-0"	A1, A3
≤ 24'-0"	< 12'-0"	A1, A2, A3, A4
> 24'-0"	ALL	A1, A3

BACKFILL REQUIREMENTS



WALL BACKFILL REQUIREMENTS

C:\USERS\JEREMY.JOHNSON\ONEDRIVE - THE QUIKRETE COMPANIES\DOCUMENTS\DRAWINGS\DWG 11/2/2022 10:35 AM

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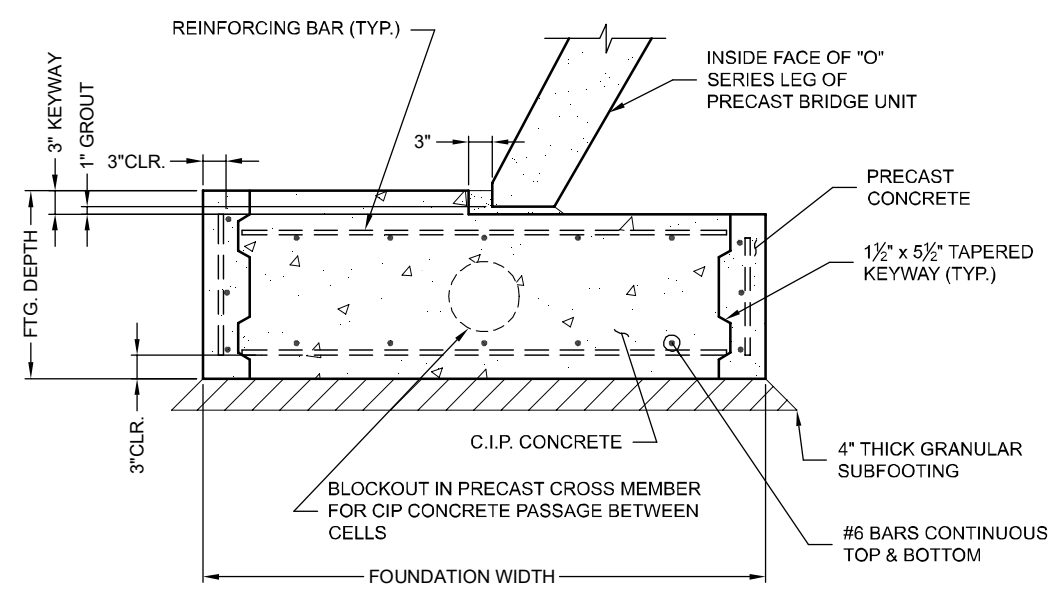
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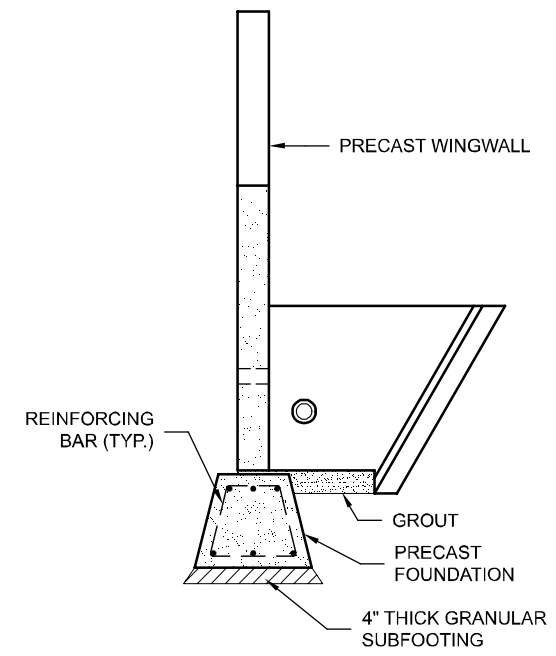
CON/SPAN O-SERIES
SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.:	D7	OF D9

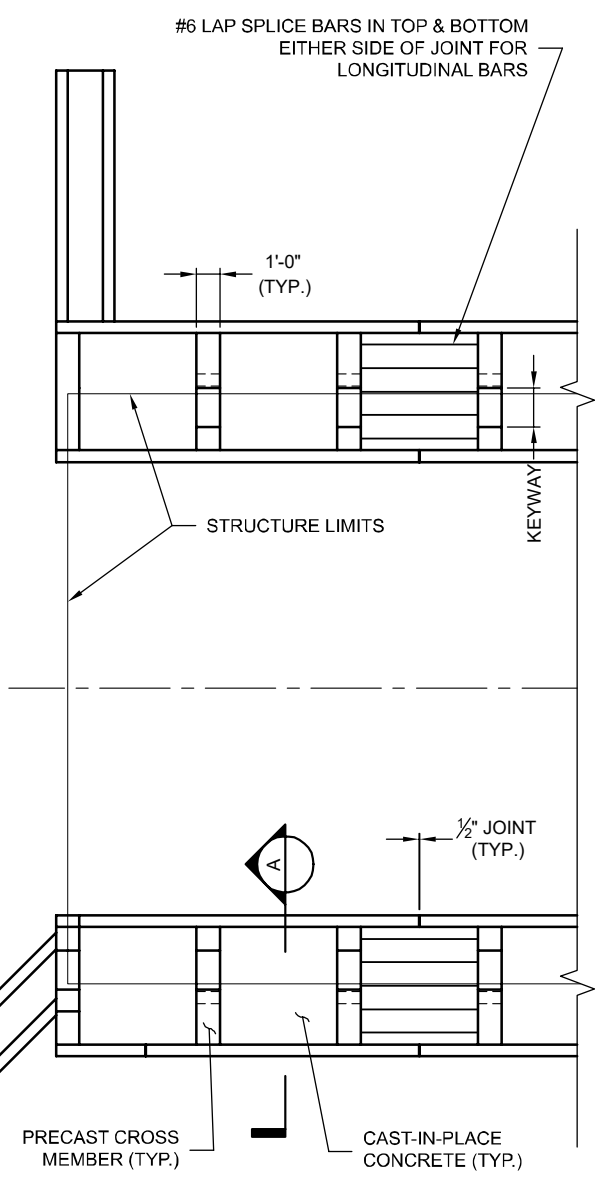
SAMPLE DRAWING ONLY



SECTION A
(NOT PROJECT SPECIFIC)



SECTION B
(NOT PROJECT SPECIFIC)



SAMPLE PARTIAL FOUNDATION PLAN
(NOT PROJECT SPECIFIC)

EXPRESS FOUNDATIONS



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CONSPAN
O-SERIES

DYOB
DRAWING

CON/SPAN O-SERIES
EXPRESS FOUNDATION SAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D8 OF D9

SAMPLE DRAWING ONLY



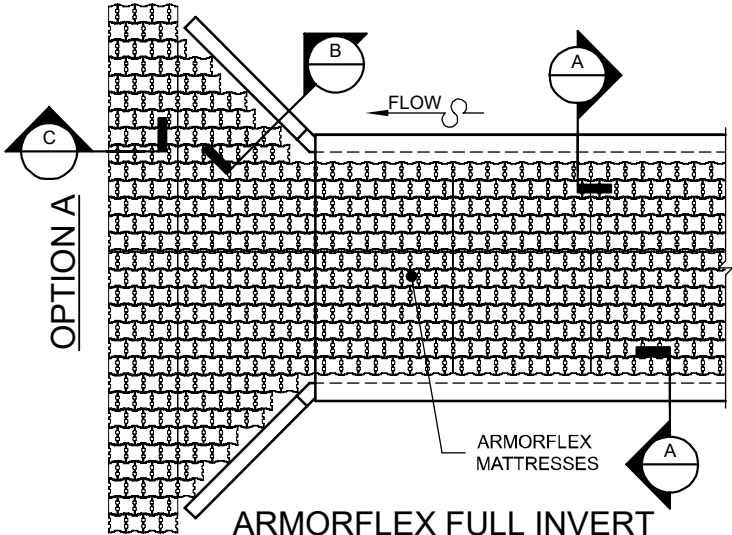
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N.T.S.



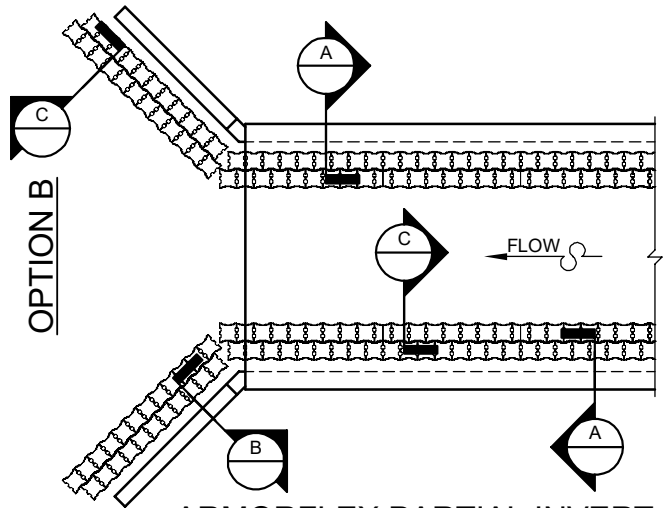
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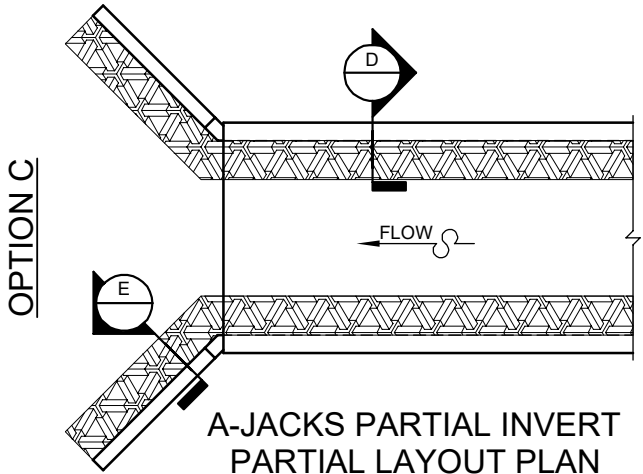
A-JACKS PARTIAL INVERT
N.T.S.



ARMORFLEX FULL INVERT
PARTIAL LAYOUT PLAN
N.T.S.

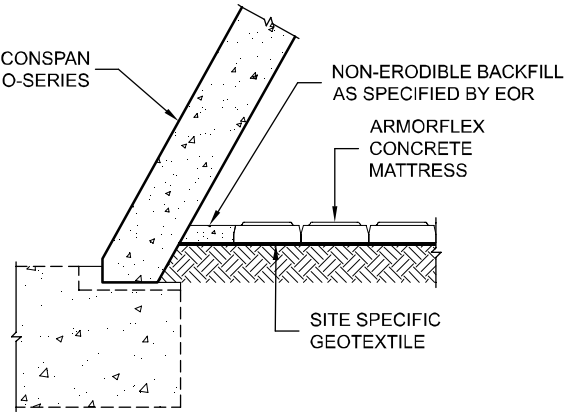


ARMORFLEX PARTIAL INVERT
PARTIAL LAYOUT PLAN
N.T.S.

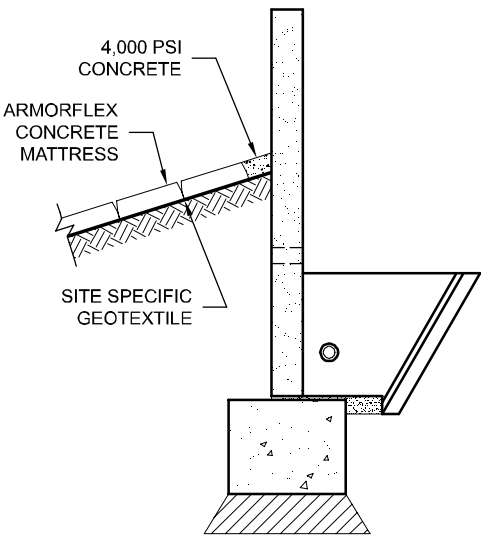


A-JACKS PARTIAL INVERT
PARTIAL LAYOUT PLAN
N.T.S.

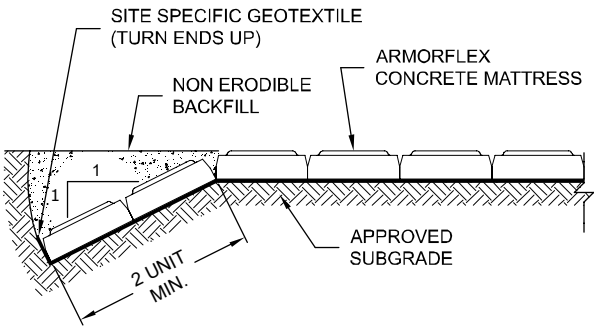
CONSIDER A COMPLETE SYSTEM WITH ARMORTEC REVETMENT



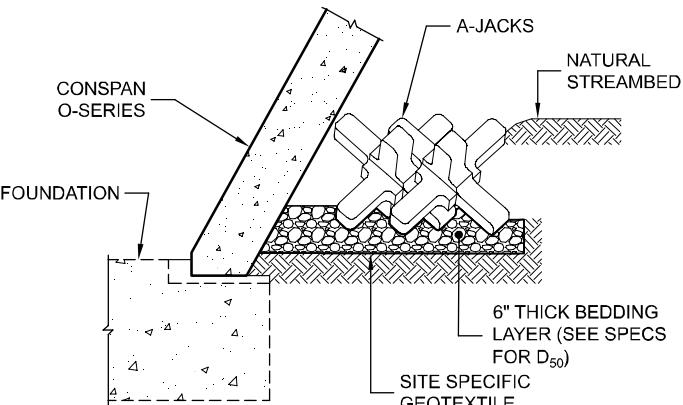
ARMORFLEX STRUCTURE TERMINATION
N.T.S.



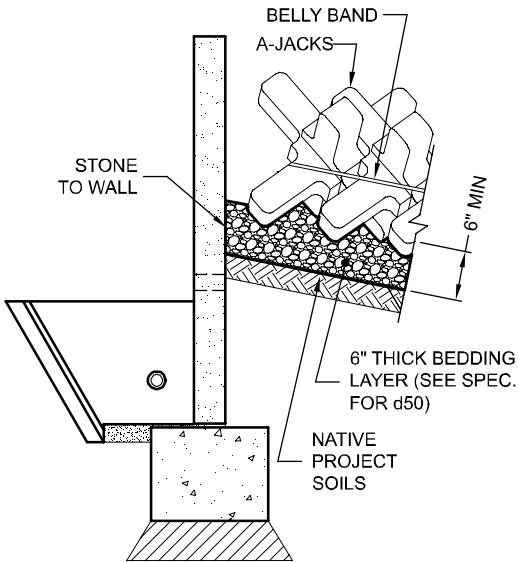
ARMORFLEX WINGWALL
TERMINATION
N.T.S.



STANDARD TERMINATION
N.T.S.



A-JACKS STRUCTURE
TERMINATION
N.T.S.



A-JACKS WINGWALL
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ARMORTEC EXAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D9 OF D9

PROJECT SUMMARY

LOCAL BRIDGE CONSULTANT

- NAME = Todd Black
- EMAIL = Todd.Black@conteches.com
- PHONE NUMBER = 913-216-3818

STRUCTURE DETAILS

- SPAN = 32' - 0"
- PRECAST RISE = 11' - 0 3/4"
- LENGTH = 72 FT.

HEADWALLS

- INLET HEADWALL HEIGHT = 2 FT.
- OUTLET HEADWALL HEIGHT = 2 FT.

FOUNDATIONS

- FOUNDATION TYPE = STRIP

WINGWALLS

- WW 1 ANGLE = 45 DEG.
- WW 1 LENGTH = 10 FT.
- WW 1 HIGH HEIGHT = 13.4 FT.
- WW 1 LOW HEIGHT = 6 FT.

- WW 2 ANGLE = 45 DEG.
- WW 2 LENGTH = 10 FT.
- WW 2 HIGH HEIGHT = 13.4 FT.
- WW 2 LOW HEIGHT = 6 FT.

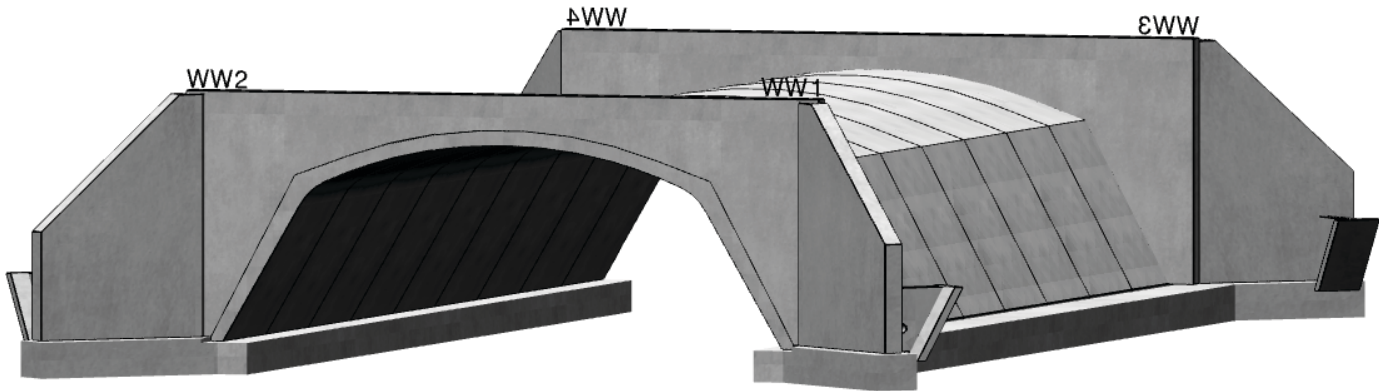
- WW 3 ANGLE = 45 DEG.
- WW 3 LENGTH = 10 FT.
- WW 3 HIGH HEIGHT = 13.4 FT.
- WW 3 LOW HEIGHT = 6 FT.

- WW 4 ANGLE = 45 DEG.
- WW 4 LENGTH = 10 FT.
- WW 4 HIGH HEIGHT = 13.4 FT.
- WW 4 LOW HEIGHT = 6 FT.

NOTES

1. THIS BRIDGE HAS BEEN DESIGNED FOR GENERAL SITE CONDITIONS. THE PROJECT ENGINEER SHALL BE RESPONSIBLE FOR THE STRUCTURE'S SUITABILITY TO THE EXISTING SITE CONDITIONS AND FOR THE HYDRAULIC EVALUATION -- INCLUDING SCOUR AND CONFIRMATION OF SOIL CONDITIONS.
2. PRIOR TO CONSTRUCTION, CONTRACTOR MUST VERIFY ALL ELEVATIONS SHOWN THROUGH THE ENGINEER.
3. ONLY CONTECH ENGINEERED SOLUTIONS LLC, THE CONSPAN APPROVED MANUFACTURER IN THE PROJECT STATE MAY PROVIDE THE STRUCTURE DESIGNED IN ACCORDANCE WITH THESE PLANS.
4. THIS DYOB DRAWING IS A CONCEPTUAL DESIGN. PLEASE WORK WITH YOUR LOCAL BRIDGE CONSULTANT FOR FURTHER SOLUTION DEVELOPMENT AND PRICING.
5. THE USE OF ANOTHER PRECAST STRUCTURE WITH THE DESIGN ASSUMPTIONS USED FOR THE CON/SPAN® STRUCTURE MAY LEAD TO SERIOUS DESIGN ERRORS. USE OF ANY OTHER PRECAST STRUCTURE WITH THIS DESIGN AND DRAWINGS VOIDS ANY CERTIFICATION OF THIS DESIGN AND WARRANTY. CONTECH ENGINEERED SOLUTIONS ASSUMES NO LIABILITY FOR DESIGN OF ANY ALTERNATE OR SIMILAR TYPE STRUCTURES.

CON/SPAN O-Series DYOB
Conspan Vehicular Crossing



PRELIMINARY
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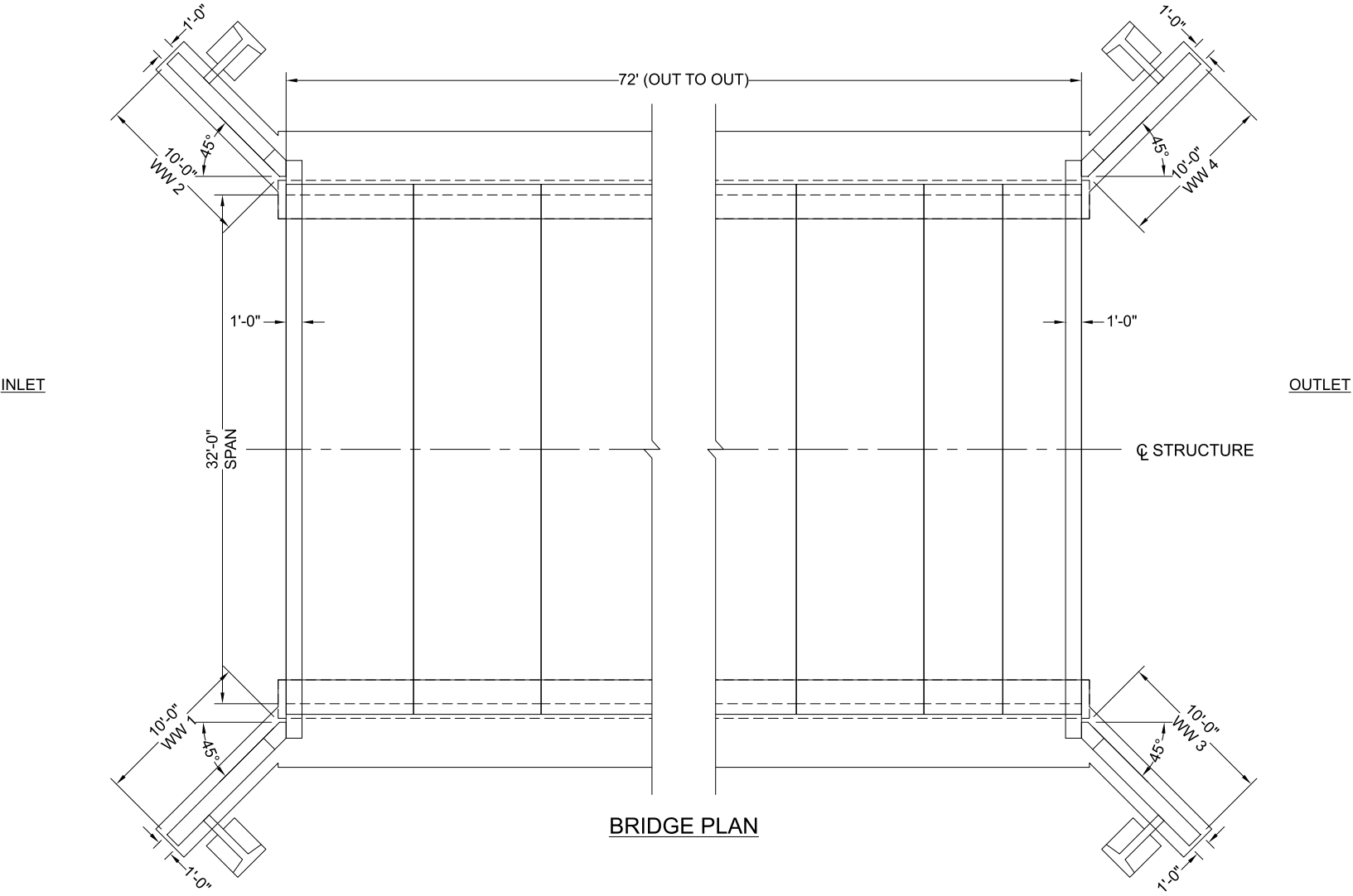
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CON/SPAN
O-SERIES

DYOB
DRAWING

DYO89558, Knob Naster State Park
Conspan Vehicular Crossing
Warrensburg, MO
O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65331	DYO No.: 89558	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.:	D1	OF D9



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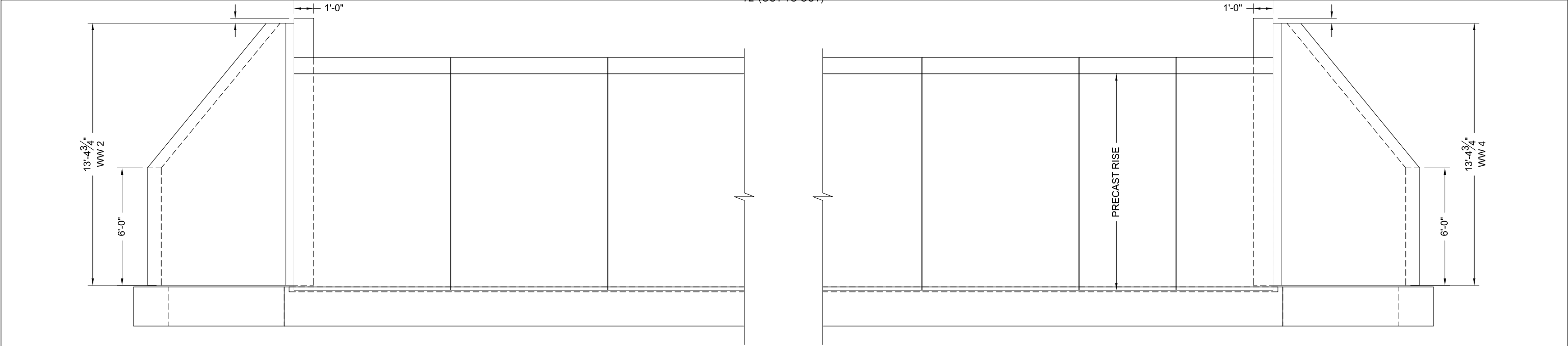
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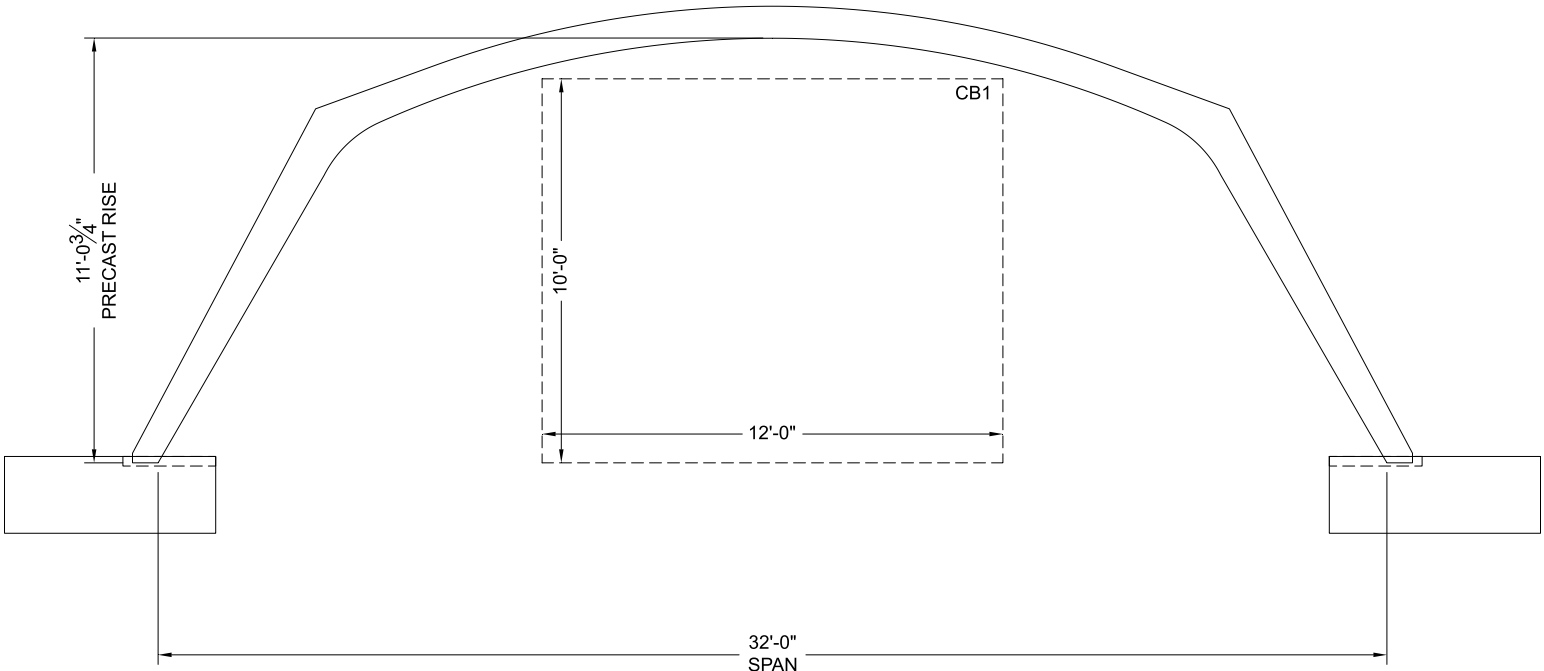
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LONGITUDINAL SECTION



CROSS SECTION

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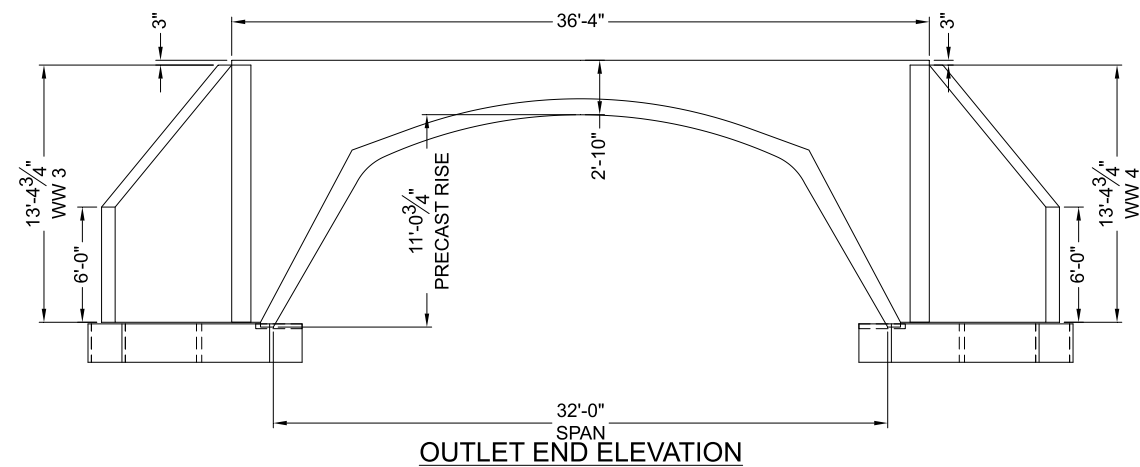
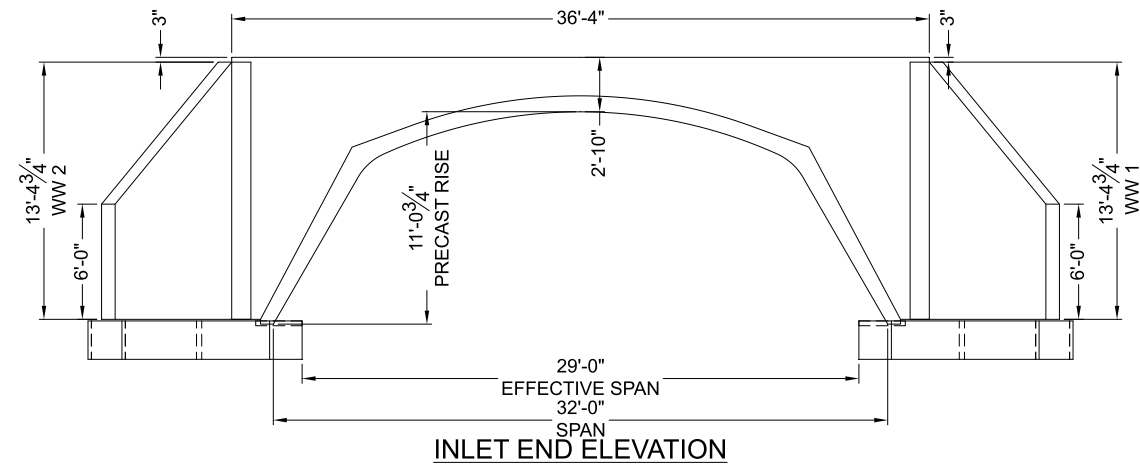
DYO89558, Knob Naster State Park

Conspan Vehicular Crossing

Warrensburg, MO

O Series, 32' Span x 11'-0 3/4" Rise

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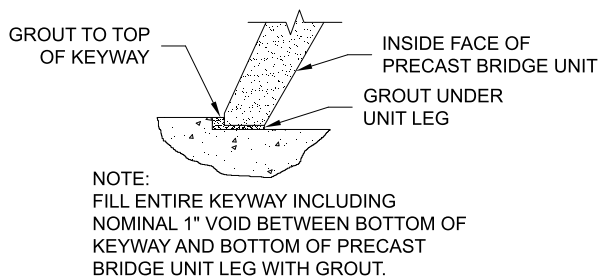
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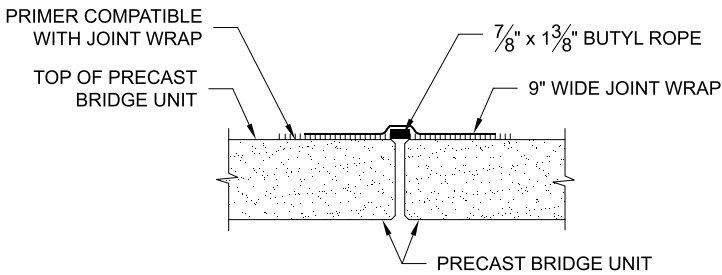
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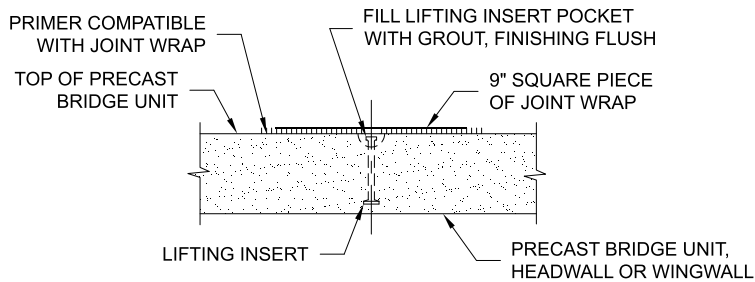
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SHEET NO.: D4 OF D9		



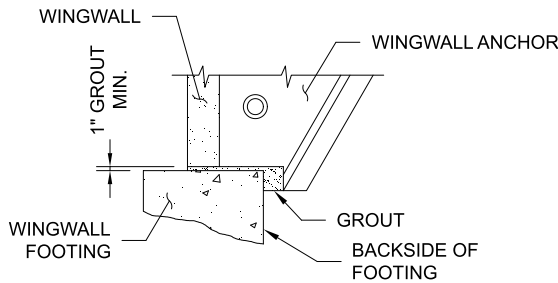
TYPICAL BRIDGE UNIT GROUT DETAIL
NOT TO SCALE



TYPICAL JOINT SEAL DETAIL
NOT TO SCALE

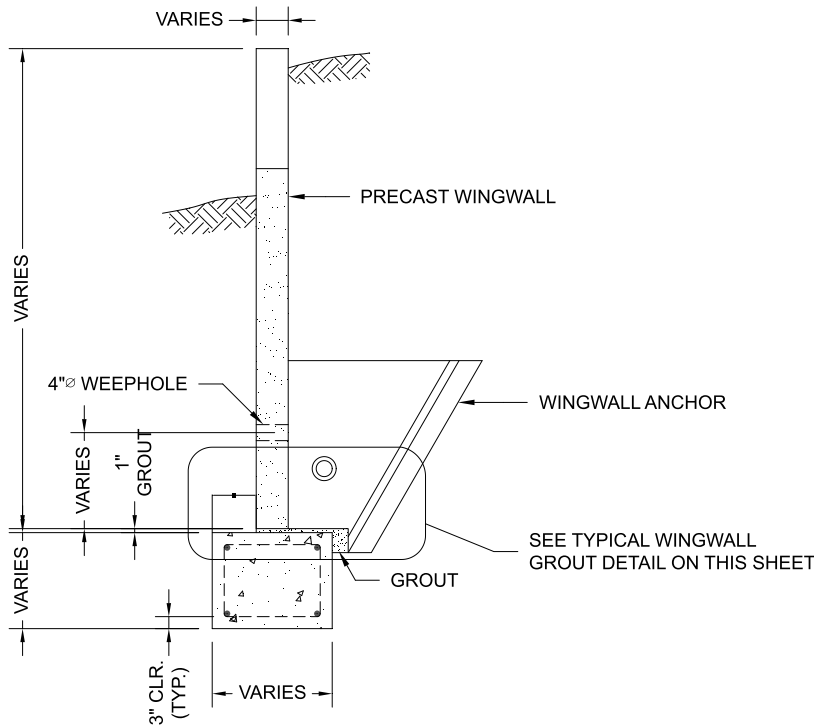


TYPICAL LIFT INSERT SEALING DETAIL
NOT TO SCALE



- NOTES:
- MINIMUM 1" GROUT UNDER WINGWALL LEG & ANCHOR STEM.
 - AREA BETWEEN WINGWALL FOOTING AND WINGWALL ANCHOR SHALL BE GROUTED SOLID BEFORE BACKFILL.
 - FORM BACKSIDE OF FOOTING TO DIMENSIONS SHOWN ON FOUNDATION PLAN.

TYPICAL WINGWALL GROUT DETAIL
NOT TO SCALE



TYPICAL WINGWALL SECTION
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SHEET NO.: D5 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS

- DESCRIPTION**
- 1.1. TYPE - THIS WORK SHALL CONSIST OF FURNISHING AND CONSTRUCTING A CON/SPAN® O-SERIES BRIDGE SYSTEM IN ACCORDANCE WITH THESE SPECIFICATIONS AND IN REASONABLY CLOSE CONFORMITY WITH THE LINES, GRADES, DESIGN AND DIMENSIONS SHOWN ON THE PLANS OR AS ESTABLISHED BY THE ENGINEER. IN SITUATIONS WHERE TWO OR MORE SPECIFICATIONS APPLY TO THIS WORK, THE MOST STRINGENT REQUIREMENTS SHALL GOVERN.
- 1.2. DESIGNATION - PRECAST REINFORCED CONCRETE CON/SPAN® O-SERIES BRIDGE UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY SPAN AND RISE. PRECAST REINFORCED CONCRETE WINGWALLS AND HEADWALLS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT, AND DEFLECTION ANGLE. PRECAST REINFORCED CONCRETE EXPRESS™ FOUNDATION UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT AND WIDTH.
- 2. DESIGN**
- 2.1. SPECIFICATIONS - THE PRECAST ELEMENTS ARE DESIGNED IN ACCORDANCE WITH THE "AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS" 8TH EDITION, ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2017. A MINIMUM OF ONE FOOT OF COVER ABOVE THE CROWN OF THE BRIDGE UNITS IS REQUIRED IN THE INSTALLED CONDITION. (UNLESS NOTED OTHERWISE ON THE SHOP DRAWINGS AND DESIGNED ACCORDINGLY.)
- 3. MATERIALS**
- 3.1. CONCRETE - THE CONCRETE FOR THE PRECAST ELEMENTS SHALL BE AIR-ENTRAINED WHEN INSTALLED IN AREAS SUBJECT TO FREEZE-THAW CONDITIONS, COMPOSED OF PORTLAND CEMENT, FINE AND COARSE AGGREGATES, ADMIXTURES AND WATER. AIR-ENTRAINED CONCRETE SHALL CONTAIN 6 ± 2 PERCENT AIR. THE AIR-ENTRAINING ADMIXTURE SHALL CONFORM TO AASHTO M154. THE MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE AS SHOWN ON THE SHOP DRAWINGS.
- 3.1.1. PORTLAND CEMENT - SHALL CONFORM TO THE REQUIREMENTS OF ASTM SPECIFICATIONS C150-TYPE I, TYPE II, OR TYPE III CEMENT.
- 3.1.2. COARSE AGGREGATE - SHALL CONSIST OF STONE HAVING A MAXIMUM SIZE OF 1 INCH. AGGREGATE SHALL MEET REQUIREMENTS FOR ASTM C33.
- 3.1.3. WATER REDUCING ADMIXTURE - THE MANUFACTURER MAY SUBMIT, FOR APPROVAL BY THE ENGINEER, A WATER-REDUCING ADMIXTURE FOR THE PURPOSE OF INCREASING WORKABILITY AND REDUCING THE WATER REQUIREMENT FOR THE CONCRETE.
- 3.1.4. CALCIUM CHLORIDE - THE ADDITION TO THE MIX OF CALCIUM CHLORIDE OR ADMIXTURES CONTAINING CALCIUM CHLORIDE WILL NOT BE PERMITTED.
- 3.1.5. MIXTURE - THE AGGREGATES, CEMENT AND WATER SHALL BE PROPORTIONED AND MIXED IN A BATCH MIXER TO PRODUCE A HOMOGENEOUS CONCRETE MEETING THE STRENGTH REQUIREMENTS OF THIS SPECIFICATION. THE PROPORTION OF PORTLAND CEMENT IN THE MIXTURE SHALL NOT BE LESS THAN 564 POUNDS (6 SACKS) PER CUBIC YARD OF CONCRETE.
- 3.2. STEEL REINFORCEMENT
- 3.2.1. THE MINIMUM STEEL YIELD STRENGTH SHALL BE 60,000 PSI, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS.
- 3.2.2. ALL REINFORCING STEEL FOR THE PRECAST ELEMENTS SHALL BE FABRICATED AND PLACED IN ACCORDANCE WITH THE DETAILED SHOP DRAWINGS SUBMITTED BY THE MANUFACTURER.
- 3.2.3. REINFORCEMENT SHALL CONSIST OF WELDED WIRE REINFORCING CONFORMING TO ASTM SPECIFICATION A 1064, OR DEFORMED STEEL BARS CONFORMING TO ASTM SPECIFICATION A 615, GRADE 60. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY CONSIST OF WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS.
- 3.3. STEEL HARDWARE
- 3.3.1. BOLTS AND THREADED RODS FOR WINGWALL CONNECTIONS SHALL CONFORM TO ASTM A 307. NUTS SHALL CONFORM TO AASHTO M292 (ASTM A194) GRADE 2H. ALL BOLTS, THREADED RODS AND NUTS USED IN WINGWALL CONNECTIONS SHALL BE MECHANICALLY ZINC COATED IN ACCORDANCE WITH ASTM B695 CLASS 50.
- 3.3.2. STRUCTURAL STEEL FOR WINGWALL CONNECTION PLATES AND PLATE WASHERS SHALL CONFORM TO AASHTO M 270 (ASTM A 709) GRADE 36 AND SHALL BE HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).
- 3.3.3. INSERTS FOR WINGWALLS SHALL BE 1" DIAMETER TWO-BOLT PRESET WINGWALL ANCHORS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED IN ACCORDANCE WITH ASTM B633 SC-1.
- 3.3.4. FERRULE LOOP INSERTS SHALL BE F-64 FERRULE LOOP INSERTS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED.
- 3.3.5. HOOK BOLTS USED IN ATTACHED HEADWALL CONNECTIONS SHALL BE ASTM A307.
- 3.3.6. INSERTS FOR DETACHED HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL, EXPANDED COIL INSERTS AS MANUFACTURED BY DAYTON SUPERIOR

CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700. COIL RODS AND NUTS USED IN HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL. WASHERS USED IN HEADWALL CONNECTIONS SHALL BE EITHER AISI TYPE 304 STAINLESS STEEL PLATE WASHERS OR AASHTO M270 (ASTM A709) GRADE 36 PLATE WASHERS HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123). MECHANICAL SPLICES OF REINFORCING BARS SHALL BE MADE USING THE DOWEL BAR SPLICER SYSTEM AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700, AND SHALL CONSIST OF THE DBDI SPLICE SYSTEM (DOWEL BAR SPLICER AND DOWEL-IN), OR AS MANUFACTURED BY BARSPLICE PRODUCTS INC, DAYTON, OHIO, (937)-275-8700, AND SHALL CONSIST OF BARSPLICER XP TYPE 2 SYSTEM.

- MANUFACTURE OF PRECAST ELEMENTS - SUBJECT TO THE PROVISIONS OF SECTION 5, BELOW, THE PRECAST ELEMENT DIMENSION AND REINFORCEMENT DETAILS SHALL BE AS PRESCRIBED IN THE PLAN AND SHOP DRAWINGS PROVIDED BY THE MANUFACTURER.
- 4.1. FORMS - THE FORMS USED IN MANUFACTURE SHALL BE SUFFICIENTLY RIGID AND ACCURATE TO MAINTAIN THE REQUIRED PRECAST ELEMENT DIMENSIONS WITHIN THE PERMISSIBLE VARIATIONS GIVEN IN SECTION 5 OF THESE SPECIFICATIONS. ALL CASTING SURFACES SHALL BE OF A SMOOTH MATERIAL.
- 4.2. PLACEMENT OF REINFORCEMENT
- 4.2.1. PLACEMENT OF REINFORCEMENT IN PRECAST BRIDGE UNITS - THE COVER OF CONCRETE OVER THE OUTSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 2" MINIMUM. THE COVER OF CONCRETE OVER THE INSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 1½" MINIMUM, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS. THE CLEAR DISTANCE OF THE END CIRCUMFERENTIAL WIRES SHALL NOT BE LESS THAN 1" NOR MORE THAN 2" FROM THE ENDS OF EACH SECTION. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING SINGLE OR MULTIPLE LAYERS OF WELDED WIRE FABRIC (NOT TO EXCEED 3 LAYERS), SUPPLEMENTED WITH A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS, WHEN NECESSARY. WELDED WIRE FABRIC SHALL BE COMPOSED OF CIRCUMFERENTIAL AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE BRIDGE UNIT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW. THE ENDS OF THE LONGITUDINAL DISTRIBUTION REINFORCEMENT SHALL BE NOT MORE THAN 3" AND NOT LESS THAN 1½" FROM THE ENDS OF THE BRIDGE UNIT.
- 4.2.2. BENDING OF REINFORCEMENT FOR PRECAST BRIDGE UNITS - THE OUTSIDE AND INSIDE CIRCUMFERENTIAL REINFORCING STEEL FOR THE CORNERS OF THE BRIDGE SHALL BE BENT TO SUCH AN ANGLE THAT IS APPROXIMATELY EQUAL TO THE CONFIGURATION OF THE BRIDGE'S OUTSIDE CORNER.
- 4.2.3. PLACEMENT OF REINFORCEMENT FOR PRECAST WINGWALLS AND HEADWALLS - THE COVER OF CONCRETE OVER THE LONGITUDINAL AND TRANSVERSE REINFORCEMENT SHALL BE 2" MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 1½" NOR MORE THAN 3". REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC, OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.
- 4.2.4. PLACEMENT OF REINFORCEMENT FOR PRECAST FOUNDATION UNITS - THE COVER OF CONCRETE OVER THE BOTTOM REINFORCEMENT SHALL BE 3 INCHES MINIMUM. THE COVER OF CONCRETE FOR ALL OTHER REINFORCEMENT SHALL BE 2 INCHES MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 2 INCHES NOR MORE THAN 3 INCHES. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.
- 4.3. LAPS, WELDS, SPACING
- 4.3.1. LAPS, WELDS, AND SPACING FOR PRECAST BRIDGE UNITS - TENSION SPLICES IN THE CIRCUMFERENTIAL REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS

MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. THE OVERLAP OF WELDED WIRE FABRIC SHALL BE MEASURED BETWEEN THE OUTER-MOST LONGITUDINAL WIRES OF EACH FABRIC SHEET. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1 FOR SPLICES OTHER THAN TENSION SPLICES. THE OVERLAP SHALL BE A MINIMUM OF 1'-0" FOR WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS. THE SPACING CENTER TO CENTER OF THE CIRCUMFERENTIAL WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 4". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL WIRES SHALL NOT BE MORE THAN 8". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL DISTRIBUTION STEEL FOR EITHER LINE OF REINFORCING IN THE TOP SLAB SHALL BE NOT MORE THAN 1'-4". LAPS, WELDS, AND SPACING FOR PRECAST WINGWALLS, HEADWALLS AND FOUNDATIONS - SPLICES IN THE REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1. THE SPACING CENTER-TO-CENTER OF THE WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 8".

4. CURING - THE PRECAST CONCRETE ELEMENTS SHALL BE CURED FOR A SUFFICIENT LENGTH OF TIME SO THAT THE CONCRETE WILL DEVELOP THE SPECIFIED COMPRESSIVE STRENGTH IN 28 DAYS OR LESS. ANY ONE OF THE FOLLOWING METHODS OF CURING OR COMBINATIONS THERE OF SHALL BE USED:
- 4.4.1. STEAM CURING - THE PRECAST ELEMENTS MAY BE LOW-PRESSURE STEAM CURED BY A SYSTEM THAT WILL MAINTAIN A MOIST ATMOSPHERE.
- 4.4.2. WATER CURING - THE PRECAST ELEMENTS MAY BE WATER CURED BY ANY METHOD THAT WILL KEEP THE SECTIONS MOIST.
- 4.4.3. MEMBRANE CURING - A SEALING MEMBRANE CONFORMING TO THE REQUIREMENTS OF ASTM SPECIFICATION C309 MAY BE APPLIED AND SHALL BE LEFT INTACT UNTIL THE REQUIRED CONCRETE COMPRESSIVE STRENGTH IS ATTAINED. THE CONCRETE TEMPERATURE AT THE TIME OF APPLICATION SHALL BE WITHIN +/- 10 DEGREES F OF THE ATMOSPHERIC TEMPERATURE. ALL SURFACES SHALL BE KEPT MOIST PRIOR TO THE APPLICATION OF THE COMPOUNDS AND SHALL BE DAMP WHEN THE COMPOUND IS APPLIED.
- 4.5. STORAGE, HANDLING & DELIVERY
- 4.5.1. STORAGE - PRECAST CONCRETE BRIDGE ELEMENTS SHALL BE LIFTED AND STORED IN "AS-CAST" POSITION. PRECAST CONCRETE HEADWALL AND WINGWALL UNITS ARE CAST, STORED AND SHIPPED IN A FLAT POSITION. THE PRECAST ELEMENTS SHALL BE STORED IN SUCH A MANNER TO PREVENT CRACKING OR DAMAGE. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE. THE UNITS SHALL NOT BE MOVED UNTIL THE CONCRETE COMPRESSIVE STRENGTH HAS REACHED A MINIMUM OF 2500 PSI (3000 PSI FOR SPANS >48 FEET), AND THEY SHALL NOT BE STORED IN AN UPRIGHT POSITION.
- 4.5.2. HANDLING - HANDLING DEVICES SHALL BE PERMITTED IN EACH PRECAST ELEMENT FOR THE PURPOSE OF HANDLING AND SETTING. SPREADER BEAMS MAY BE REQUIRED FOR THE LIFTING OF PRECAST CONCRETE BRIDGE ELEMENTS TO PRECLUDE DAMAGE FROM BENDING OR TORSION FORCES.
- 4.5.3. DELIVERY - PRECAST CONCRETE ELEMENTS MUST NOT BE SHIPPED UNTIL THE CONCRETE HAS ATTAINED THE SPECIFIED DESIGN COMPRESSIVE STRENGTH, OR AS DIRECTED BY THE DESIGN ENGINEER. PRECAST CONCRETE ELEMENTS MAY BE UNLOADED AND PLACED ON THE GROUND AT THE SITE UNTIL INSTALLED. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE.
- 4.6. QUALITY ASSURANCE - THE PRECASTER SHALL DEMONSTRATE ADHERENCE TO THE STANDARDS SET FORTH IN THE NPCA QUALITY CONTROL MANUAL. THE PRECASTER SHALL MEET EITHER SECTION 4.6.1 OR 4.6.2
- 4.6.1. CERTIFICATION - THE PRECASTER SHALL BE CERTIFIED BY THE PRECAST/PRESTRESSED CONCRETE INSTITUTE PLANT CERTIFICATION PROGRAM OR THE NATIONAL PRECAST CONCRETE ASSOCIATION'S PLANT CERTIFICATION PROGRAM PRIOR TO AND DURING PRODUCTION OF THE PRODUCTS COVERED BY THIS SPECIFICATION.
- 4.6.2. QUALIFICATIONS, TESTING AND INSPECTION
- 4.6.2.1. THE PRECASTER SHALL HAVE BEEN IN THE BUSINESS OF PRODUCING PRECAST CONCRETE PRODUCTS SIMILAR TO THOSE SPECIFIED FOR A MINIMUM OF THREE YEARS. HE SHALL MAINTAIN A PERMANENT QUALITY CONTROL DEPARTMENT OR RETAIN AN INDEPENDENT TESTING AGENCY ON A CONTINUING BASIS. THE AGENCY SHALL ISSUE A REPORT, CERTIFIED BY A LICENSED ENGINEER, DETAILING THE ABILITY OF THE PRECASTER TO PRODUCE QUALITY PRODUCTS CONSISTENT WITH INDUSTRY STANDARDS.
- 4.6.2.2. THE PRECASTER SHALL SHOW THAT THE

FOLLOWING TESTS ARE PERFORMED IN
 ACCORDANCE WITH THE ASTM STANDARDS
 INDICATED. TESTS SHALL BE PERFORMED AS
 INDICATED IN SECTION 6 OF THESE
 SPECIFICATIONS.

- 4.6.2.2.1. AIR CONTENT: C231 OR C173
4.6.2.2.2. COMPRESSIVE STRENGTH: C31,C39,C497
4.6.2.3. THE PRECASTER SHALL PROVIDE DOCUMENTATION DEMONSTRATING COMPLIANCE WITH THIS SECTION TO CONTECH® ENGINEERED SOLUTIONS AT REGULAR INTERVALS OR UPON REQUEST.
4.6.2.4. THE OWNER MAY PLACE AN INSPECTOR IN THE PLANT WHEN THE PRODUCTS COVERED BY THIS SPECIFICATION ARE BEING MANUFACTURED.
4.6.3. DOCUMENTATION - THE PRECASTER SHALL SUBMIT PRECAST PRODUCTION REPORTS TO CONTECH® ENGINEERED SOLUTIONS AS REQUIRED.
5. PERMISSIBLE VARIATIONS
5.1. BRIDGE UNITS
5.1.1. INTERNAL DIMENSIONS - THE INTERNAL DIMENSION SHALL VARY NOT MORE THAN 1% FROM THE DESIGN DIMENSIONS NOR MORE THAN 1½" WHICHEVER IS LESS.
5.1.2. SLAB AND WALL THICKNESS - THE SLAB AND WALL THICKNESS SHALL NOT BE LESS THAN THAT SHOWN IN THE DESIGN BY MORE THAN ½". A THICKNESS MORE THAN THAT REQUIRED IN THE DESIGN SHALL NOT BE CAUSE FOR REJECTION.
5.1.3. LENGTH OF OPPOSITE SURFACES - VARIATIONS IN LAYING LENGTHS OF TWO OPPOSITE SURFACES OF THE BRIDGE UNIT SHALL NOT BE MORE THAN ½" IN ANY SECTION, EXCEPT WHERE BEVELED ENDS FOR LAYING OF CURVES ARE SPECIFIED BY THE PURCHASER.
5.1.4. LENGTH OF SECTION - THE UNDERRUN IN LENGTH OF A SECTION SHALL NOT BE MORE THAN ½" IN ANY BRIDGE UNIT.
5.1.5. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½" FOR THE OUTSIDE CIRCUMFERENTIAL STEEL OR BE LESS THAN 1" FOR THE INSIDE CIRCUMFERENTIAL STEEL AS MEASURED TO THE EXTERNAL OR INTERNAL SURFACE OF THE BRIDGE. THESE TOLERANCES OR COVER REQUIREMENTS DO NOT APPLY TO MATING SURFACES OF THE JOINTS.
5.1.6. AREA OF REINFORCEMENT - THE AREAS OF STEEL REINFORCEMENT SHALL BE THE DESIGN STEEL AREAS AS SHOWN IN THE MANUFACTURER'S SHOP DRAWINGS. STEEL AREAS GREATER THAN THOSE REQUIRED SHALL NOT BE CAUSE FOR REJECTION. THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCEMENT SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCEMENT.
- 5.2. WINGWALLS & HEADWALLS
5.2.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.2.2. LENGTH/HEIGHT OF WALL SECTIONS - THE LENGTH AND HEIGHT OF THE WALL SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.2.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
5.2.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.
- 5.3. FOUNDATION UNITS
5.3.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.3.2. LENGTH/ HEIGHT/WIDTH OF FOUNDATION SECTIONS - THE LENGTH, HEIGHT AND WIDTH OF THE FOUNDATION UNITS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.3.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
5.3.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.
6. TESTING/ INSPECTION
6.1. TESTING
6.1.1. TYPE OF TEST SPECIMEN - CONCRETE COMPRESSIVE STRENGTH SHALL BE DETERMINED FROM COMPRESSION TESTS MADE ON CYLINDERS OR CORES. FOR CYLINDER TESTING, A MINIMUM OF 4 CYLINDERS SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. FOR CORE TESTING, A MINIMUM OF 2 CORES SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. EACH ELEMENT SHALL BE CONSIDERED SEPARATELY FOR THE PURPOSE OF TESTING AND ACCEPTANCE.
6.1.2. COMPRESSION TESTING - CYLINDERS SHALL BE MADE AND TESTED AS PRESCRIBED BY THE ASTM C39 SPECIFICATION. CYLINDERS SHALL BE CURED IN THE SAME ENVIRONMENT AS THE BRIDGE ELEMENTS. CORES SHALL BE OBTAINED AND TESTED FOR COMPRESSIVE STRENGTH FROM EACH ELEMENT IN ACCORDANCE WITH THE PROVISIONS OF THE

ASTM C42 SPECIFICATION. ACCEPTABILITY OF CYLINDER TESTS - WHEN THE AVERAGE COMPRESSIVE STRENGTH OF ALL CYLINDERS TESTED IS EQUAL TO OR GREATER THAN THE DESIGN COMPRESSIVE STRENGTH, AND NOT MORE THAN 10% OF THE CYLINDERS TESTED HAVE A COMPRESSIVE STRENGTH LESS THAN THE DESIGN CONCRETE STRENGTH, AND NO CYLINDER TESTED HAS A COMPRESSIVE STRENGTH LESS THAN 90% OF THE REQUIRED CONCRETE STRENGTH, THEN THE ELEMENT SHALL BE ACCEPTED. WHEN THE COMPRESSIVE STRENGTH OF THE CYLINDERS TESTED DOES NOT CONFORM TO THESE ACCEPTANCE CRITERIA, THE ACCEPTABILITY OF THE ELEMENT MAY BE DETERMINED AS DESCRIBED IN SECTION 6.1.4. BELOW.

- 6.1.4. ACCEPTABILITY OF CORE TESTS - THE COMPRESSIVE STRENGTH OF THE CONCRETE IN A BRIDGE ELEMENT IS ACCEPTABLE WHEN EACH CORE TEST STRENGTH IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH. WHEN THE COMPRESSIVE STRENGTH OF A CORE TESTED IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN MAY BE RE-CORED. WHEN THE COMPRESSIVE STRENGTH OF THE RE-CORE IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH, THE COMPRESSIVE STRENGTH OF THE CONCRETE IN THAT BRIDGE ELEMENT IS ACCEPTABLE.
- 6.1.4.1. WHEN THE COMPRESSIVE STRENGTH OF ANY RECORE IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN SHALL BE REJECTED.
- 6.1.4.2. PLUGGING CORE HOLES - THE CORE HOLES SHALL BE PLUGGED AND SEALED BY THE MANUFACTURER IN A MANNER SUCH THAT THE ELEMENTS WILL MEET ALL OF THE TEST REQUIREMENTS OF THIS SPECIFICATION. PRECAST ELEMENTS SO SEALED SHALL BE CONSIDERED SATISFACTORY FOR USE.
- 6.1.4.3. TEST EQUIPMENT - EVERY MANUFACTURER FURNISHING PRECAST ELEMENTS UNDER THIS SPECIFICATION SHALL FURNISH ALL FACILITIES AND PERSONNEL NECESSARY TO CARRY OUT THE TEST REQUIRED.
- INSPECTION - THE QUALITY OF MATERIALS, THE PROCESS OF MANUFACTURE, AND THE FINISHED PRECAST ELEMENTS SHALL BE SUBJECT TO INSPECTION BY THE PURCHASER.

7. JOINTS
THE BRIDGE UNITS SHALL BE PRODUCED WITH FLAT BUTT ENDS. THE ENDS OF THE BRIDGE UNITS SHALL BE SUCH THAT WHEN THE SECTIONS ARE LAID TOGETHER THEY WILL MAKE A CONTINUOUS LINE WITH A SMOOTH INTERIOR FREE OF APPRECIABLE IRREGULARITIES, ALL COMPATIBLE WITH THE PERMISSIBLE VARIATIONS IN SECTION 5, ABOVE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED $\frac{3}{4}$ ".
8. WORKMANSHIP/ FINISH
THE BRIDGE UNITS, WINGWALLS, HEADWALLS AND FOUNDATION UNITS SHALL BE SUBSTANTIALLY FREE OF FRACTURES. THE ENDS OF THE BRIDGE UNITS SHALL BE NORMAL TO THE WALLS AND CENTERLINE OF THE BRIDGE SECTION, WITHIN THE LIMITS OF THE VARIATIONS GIVEN IN SECTION 5, ABOVE, EXCEPT WHERE BEVELED ENDS ARE SPECIFIED. THE FACES OF THE WINGWALLS AND HEADWALLS SHALL BE PARALLEL TO EACH OTHER, WITHIN THE LIMITS OF VARIATIONS GIVEN IN SECTION 5, ABOVE. THE SURFACE OF THE PRECAST ELEMENTS SHALL BE A SMOOTH STEEL FORM OR TROWELED SURFACE. TRAPPED AIR POCKETS CAUSING SURFACE DEFECTS SHALL BE CONSIDERED AS PART OF A SMOOTH, STEEL FORM FINISH.
9. REPAIRS
PRECAST ELEMENTS MAY BE REPAIRED, IF NECESSARY, BECAUSE OF IMPERFECTIONS IN MANUFACTURE OR HANDLING DAMAGE AND WILL BE ACCEPTABLE IF, IN THE OPINION OF THE PURCHASER, THE REPAIRS ARE SOUND, PROPERLY FINISHED AND CURED, AND THE REPAIRED SECTION CONFORMS TO THE REQUIREMENTS OF THIS SPECIFICATION.
10. REJECTION
THE PRECAST ELEMENTS SHALL BE SUBJECT TO REJECTION ON ACCOUNT OF ANY OF THE SPECIFICATION REQUIREMENTS. INDIVIDUAL PRECAST ELEMENTS MAY BE REJECTED BECAUSE OF ANY OF THE FOLLOWING:
- 10.1. FRACTURES OR CRACKS PASSING THROUGH THE WALL, EXCEPT FOR A SINGLE END CRACK THAT DOES NOT EXCEED ONE HALF THE THICKNESS OF THE WALL.
- 10.2. DEFECTS THAT INDICATE PROPORTIONING, MIXING, AND MOLDING NOT IN COMPLIANCE WITH SECTION 4 OF THESE SPECIFICATIONS.
- 10.3. HONEYCOMBED OR OPEN TEXTURE.
- 10.4. DAMAGED ENDS, WHERE SUCH DAMAGE WOULD PREVENT MAKING A SATISFACTORY JOINT.

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DYOB
 DRAWING

CON/SPAN O-SERIES SPECIFICATIONS

PROJECT NO.:	SEQ. NO.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.: D6 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS (CONT'D)

11. **MARKING**
EACH BRIDGE UNIT SHALL BE CLEARLY MARKED BY WATERPROOF PAINT. THE FOLLOWING SHALL BE SHOWN ON THE INSIDE OF THE VERTICAL LEG OF THE BRIDGE SECTION:
BRIDGE SPAN X BRIDGE RISE
DATE OF MANUFACTURE
NAME OR TRADEMARK OF THE MANUFACTURER

12. **INSTALLATION PREPARATION**
TO ENSURE CORRECT INSTALLATION OF THE PRECAST CONCRETE BRIDGE SYSTEM, CARE AND CAUTION MUST BE EXERCISED IN FORMING THE SUPPORT AREAS FOR BRIDGE UNITS, HEADWALL, AND WINGWALL ELEMENTS. EXERCISING SPECIAL CARE WILL FACILITATE THE RAPID INSTALLATION OF THE PRECAST COMPONENTS.

- 12.1. **FOOTINGS**
DO NOT OVER EXCAVATE FOUNDATIONS UNLESS DIRECTED BY SITE SOIL ENGINEER TO REMOVE UNSUITABLE SOIL.

THE SITE SOILS ENGINEER SHALL CERTIFY THAT THE BEARING CAPACITY MEETS OR EXCEEDS THE FOOTING DESIGN REQUIREMENTS, PRIOR TO THE CONTRACTOR POURING OF THE FOOTINGS.

THE BRIDGE UNITS AND WINGWALLS SHALL BE INSTALLED ON EITHER PRECAST OR CAST-IN-PLACE CONCRETE FOOTINGS. THE SIZE AND ELEVATION OF THE FOOTINGS SHALL BE AS DESIGNED BY THE ENGINEER. A KEYWAY SHALL BE FORMED IN THE TOP SURFACE OF THE BRIDGE FOOTING AS SPECIFIED ON THE PLANS. NO KEYWAY IS REQUIRED IN THE WINGWALL FOOTINGS, UNLESS OTHERWISE SPECIFIED ON THE PLANS.

THE FOOTINGS SHALL BE GIVEN A SMOOTH FLOAT FINISH AND SHALL REACH A COMPRESSIVE STRENGTH OF 2,000 PSI BEFORE PLACEMENT OF THE BRIDGE AND WINGWALL ELEMENTS. BACKFILLING SHALL NOT BEGIN UNTIL THE FOOTING HAS REACHED THE FULL DESIGN COMPRESSIVE STRENGTH.

THE FOOTING SURFACE SHALL BE CONSTRUCTED IN ACCORDANCE WITH GRADES SHOWN ON THE PLANS. WHEN TESTED WITH A 10'-0" STRAIGHT EDGE, THE SURFACE SHALL NOT VARY MORE THAN 1/4" IN 10'-0".

IF A PRECAST CONCRETE FOOTING IS USED, THE CONTRACTOR SHALL PREPARE A 4" THICK BASE LAYER OF COMPACTED GRANULAR MATERIAL THE FULL WIDTH OF THE FOOTING PRIOR TO PLACING THE PRECAST FOOTING.

THE FOUNDATIONS FOR PRECAST CONCRETE BRIDGE ELEMENTS AND WINGWALLS MUST BE CONNECTED BY REINFORCEMENT TO FORM ONE MONOLITHIC BODY. EXPANSION JOINTS SHALL NOT BE USED.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE CONSTRUCTION OF THE FOUNDATIONS PER THE PLANS AND SPECIFICATIONS.

13. **INSTALLATION**
13.1. **GENERAL** - THE INSTALLATION OF THE PRECAST CONCRETE ELEMENTS SHALL BE AS EXPLAINED IN THE PUBLICATION CON/SPAN BRIDGE SYSTEMS INSTALLATION HANDBOOK.

- 13.1.1. **LIFTING** - IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO ENSURE THAT A CRANE OF THE CORRECT LIFTING CAPACITY IS AVAILABLE TO HANDLE THE PRECAST CONCRETE UNITS. THIS CAN BE ACCOMPLISHED BY USING THE WEIGHTS GIVEN FOR THE PRECAST CONCRETE COMPONENTS AND BY DETERMINING THE LIFTING REACH FOR EACH CRANE UNIT. SITE CONDITIONS MUST BE CHECKED WELL IN ADVANCE OF SHIPPING TO ENSURE PROPER CRANE LOCATION AND TO AVOID ANY LIFTING RESTRICTIONS. THE LIFT ANCHORS OR HOLES PROVIDED IN EACH UNIT ARE THE ONLY MEANS TO BE USED TO LIFT THE ELEMENTS. THE PRECAST CONCRETE ELEMENTS MUST NOT BE SUPPORTED OR RAISED BY OTHER MEANS THAN THOSE GIVEN IN THE MANUALS AND DRAWINGS WITHOUT WRITTEN APPROVAL FROM CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2. **CONSTRUCTION EQUIPMENT WEIGHT RESTRICTIONS** - IN NO CASE SHALL EQUIPMENT OPERATING IN EXCESS OF THE DESIGN LOAD (HL-93) BE PERMITTED OVER THE BRIDGE UNITS UNLESS APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2.1. IN THE IMMEDIATE AREA OF THE BRIDGE UNITS, THE FOLLOWING RESTRICTIONS FOR THE USE OF HEAVY CONSTRUCTION MACHINERY DURING BACKFILLING OPERATIONS APPLY:

- NO CONSTRUCTION EQUIPMENT SHALL CROSS THE BARE PRECAST CONCRETE BRIDGE UNIT.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 4" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 10 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 1'-0" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 30 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED THE DESIGN COVER, OR 2'-0" MINIMUM, OVER THE CROWN OF THE PRECAST CONCRETE BRIDGE, CONSTRUCTION EQUIPMENT WITHIN THE DESIGN LOAD LIMITS FOR THE ROAD MAY CROSS THE PRECAST CONCRETE BRIDGE.

- 13.2. **LEVELING PAD/SHIMS** - THE BRIDGE UNITS AND WINGWALLS SHALL BE SET ON HARDBOARD SHIMS CONFORMING TO ASTM D1037 OR PLASTIC SHIMS (DAYTON SUPERIOR P-80, P-81 OR APPROVED EQUAL) MEASURING 5" x 5", MINIMUM, UNLESS SHOWN OTHERWISE ON THE PLANS. A MINIMUM GAP OF 1/2" SHALL BE PROVIDED BETWEEN THE FOOTING AND THE BOTTOM OF THE BRIDGE'S

VERTICAL LEGS OR THE BOTTOM OF THE WINGWALL. ALSO, A SUPPLY OF 1/4", 1/2" AND 3/8" THICK HARDBOARD OR PLASTIC SHIMS FOR VARIOUS SHIMMING PURPOSES SHALL BE ON SITE.

- 13.3. **PLACEMENT OF BRIDGE UNITS** - THE BRIDGE UNITS SHALL BE PLACED AS SHOWN ON THE ENGINEER'S PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED 1/4".

- 13.4. IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN THE STRUCTURE SPAN DURING ALL PHASES OF INSTALLATION. DUE TO THE ARCH SHAPE, BRIDGE ELEMENTS WILL TEND TO SPREAD UNDER SELF-WEIGHT. IT IS IMPERATIVE THAT ANY LATERAL SPREADING OF THE BRIDGE ELEMENTS BE AVOIDED DURING AND AFTER THEIR PLACEMENT. GENERALLY, HORIZONTAL CABLE TIES OR TIE RODS ARE SHIPPED IN THE LARGER BRIDGE ELEMENTS TO ASSIST IN PREVENTING THIS SPREADING. CABLE TIES/TIE RODS SHALL NOT BE REMOVED UNTILL BRIDGE UNITS ARE GROUTED AND GROUT HAS CURED. IT IS RECOMMENDED THAT TEMPORARY HARDWOOD BLOCKS BE USED IN CONJUNCTION WITH THE CABLE TIES/TIE RODS TO MAINTAIN SPAN. IF, HOWEVER, DUE TO SITE RESTRICTIONS, THESE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO PLACEMENT OF THE BRIDGE ELEMANTS, THE CONTRACTOR MUST NOTIFY CONTECH (MANUFACTURER) AND REQUEST A SUGGESTED INSTALLATION PROCEDURE.

IN ADDITION, IF THE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO SETTING ARCH UNITS, THE FOLLOWING QUALITY CONTROL PROCEDURE MUST BE FOLLOWED:

- 1) FIND "MEASURED SPAN" UPON ARCH UNIT'S DELIVERY TO SITE, PRIOR TO LIFTING FROM TRUCK AND REMOVING CABLE TIES/TIE RODS. "MEASURED SPAN" SHALL BE THE AVERAGE OF (3) SPAN MEASUREMENTS ALONG THE LAY LENGTH OF THE ARCH UNIT.
- 2) AFTER SETTING OF BRIDGE UNIT ON THE FOUNDATION, VERIFY THE SPAN. THIS "INSTALLED SPAN MEASUREMENT" SHALL NOT EXCEED THE MAXIMUM OF:
A) THE NOMINAL SPAN + 1/4" OR
B) THE "MEASURED SPAN"

IF THE "INSTALLED SPAN MEASUREMENT" EXCEEDS THIS AMOUNT, THE ARCH UNIT SHALL BE LIFTED AND RE-SET UNTIL THE "INSTALLED SPAN MEASUREMENT" MEETS THE LIMITS.

- 13.5. **PLACEMENT OF WINGWALLS, HEADWALLS AND FOUNDATION UNITS** - THE WINGWALLS, HEADWALLS AND FOUNDATIONS SHALL BE PLACED AS SHOWN ON THE PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE.

- 13.6. **JOINT PROTECTION AND SUBSURFACE DRAINAGE**

- 13.6.1. **EXTERNAL PROTECTION OF JOINTS** - THE BUTT JOINT MADE BY TWO ADJOINING BRIDGE UNITS SHALL BE COVERED WITH A 7/8" x 1 1/2" PREFORMED BITUMINOUS JOINT SEALANT AND A MINIMUM OF A 9" WIDE JOINT WRAP. THE SURFACE SHALL BE FREE OF DIRT BEFORE APPLYING THE JOINT MATERIAL. A PRIMER COMPATIBLE WITH THE JOINT WRAP TO BE USED SHALL BE APPLIED FOR A MINIMUM WIDTH OF 9" ON EACH SIDE OF THE JOINT. THE EXTERNAL WRAP SHALL BE CS212 BY CONCRETE SEALANTS INC., EZ-WRAP RUBBER BY PRESS-SEAL GASKET CORPORATION, SEAL WRAP BY MAR MAC MANUFACTURING CO. INC. OR APPROVED EQUAL. THE JOINT SHALL BE COVERED CONTINUOUSLY FROM THE BOTTOM OF ONE BRIDGE SECTION LEG, ACROSS THE TOP OF THE BRIDGE AND TO THE OPPOSITE BRIDGE SECTION LEG. ANY LAPS THAT RESULT IN THE JOINT WRAP SHALL BE A MINIMUM OF 6" LONG WITH THE OVERLAP RUNNING DOWNHILL.

- 13.6.2. **IN ADDITION TO THE JOINTS BETWEEN BRIDGE UNITS, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE HEADWALL SHALL ALSO BE SEALED AS DESCRIBED ABOVE. IF PRECAST WINGWALLS ARE USED, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE WINGWALL SHALL BE SEALED WITH A 2'-0" STRIP OF FILTER FABRIC. ALSO, IF LIFT HOLES ARE FORMED IN THE BRIDGE UNITS, THEY SHALL BE PRIMED AND COVERED WITH A 9" x 9" SQUARE OF JOINT WRAP.**

- 13.6.3. **DURING THE BACKFILLING OPERATION, CARE SHALL BE TAKEN TO KEEP THE JOINT WRAP IN ITS PROPER LOCATION OVER THE JOINT.**

- 13.6.4. **SUBSOIL DRAINAGE SHALL BE AS DIRECTED BY THE ENGINEER.**

- 13.7. **GROUTING**

- 13.7.1. **GROUTING SHALL NOT BE PERFORMED WHEN TEMPERATURES ARE EXPECTED TO GO BELOW 35° FOR A PERIOD OF 72 HOURS. GROUTING SHOULD BE COMPLETED AS SOON AS PRACTICAL AFTER PRECAST ARCHES HAVE BEEN INSTALLED. FILL THE BRIDGE-FOUNDATION KEYWAY WITH CEMENT GROUT (PORTLAND CEMENT AND WATER OR CEMENT MORTAR COMPOSED OF PORTLAND CEMENT, SAND AND WATER) WITH A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 3000 PSI. VIBRATE AS REQUIRED TO ENSURE THAT THE ENTIRE KEY AROUND THE BRIDGE ELEMENT IS COMPLETELY FILLED. IF BRIDGE ELEMENTS HAVE BEEN SET WITH TEMPORARY TIES (CABLES, BARS, ETC.) GROUT MUST ATTAIN A MINIMUM COMPRESSIVE STRENGTH OF 1500 PSI BEFORE TIES MAY BE REMOVED.**

- 13.7.2. **ALL GROUT SHALL HAVE A MAXIMUM AGGREGATE SIZE OF 1/4".**

- 13.7.3. **LIFTING AND ERECTION ANCHOR RECESSES SHALL BE FILLED WITH GROUT.**

- 13.7.4. **AFTER GROUT HAS REACHED ITS DESIGN STRENGTH THE TEMPORARY HARDWOOD WEDGES SHALL BE REMOVED AND THEIR HOLES FILLED WITH GROUT.**

- 13.8. **BACKFILL**

- 13.8.1. **DO NOT PERFORM BACKFILLING DURING WET OR FREEZING**

WEATHER.
13.8.2. **NO BACKFILL SHALL BE PLACED AGAINST ANY STRUCTURAL ELEMENTS UNTIL THEY HAVE BEEN APPROVED BY THE ENGINEER.**

- 13.8.3. **BACKFILL SHALL BE CONSIDERED AS ALL REPLACED EXCAVATION AND NEW EMBANKMENT ADJACENT TO THE PRECAST CONCRETE ELEMENTS. THE PROJECT CONSTRUCTION AND MATERIAL SPECIFICATIONS, WHICH INCLUDE THE SPECIFICATIONS FOR EXCAVATION FOR STRUCTURES AND ROADWAY EXCAVATION AND EMBANKMENT CONSTRUCTION, SHALL APPLY EXCEPT AS MODIFIED IN THIS SECTION.**

- 13.8.4. **BACKFILL ZONES:**

- IN-SITU SOIL
- ZONE A: CONSTRUCTED EMBANKMENT OR OVERFILL.
- ZONE B: FILL THAT IS DIRECTLY ASSOCIATED WITH PRECAST CONCRETE BRIDGE INSTALLATION.
- ZONE C: ROAD STRUCTURE.

- 13.8.5. **REQUIRED BACKFILL PROPERTIES**

- 13.8.5.1. **IN-SITU SOIL** - NATURAL GROUND IS TO BE SUFFICIENTLY STABLE TO ALLOW EFFECTIVE SUPPORT TO THE PRECAST CONCRETE BRIDGE UNITS. AS A GUIDE, THE EXISTING NATURAL GROUND SHOULD BE OF SIMILAR QUALITY AND DENSITY TO ZONE B MATERIAL FOR MINIMUM LATERAL DIMENSION OF ONE BRIDGE SPAN OUTSIDE OF THE BRIDGE FOOTING.

- 13.8.5.2. **ZONE A - ZONE A REQUIRES FILL MATERIAL WITH SPECIFICATIONS AND COMPACTING PROCEDURES EQUAL TO THAT FOR NORMAL ROAD EMBANKMENTS.**

- 13.8.5.3. **ZONE B - GENERALLY, SOILS SHALL BE REASONABLY FREE OF ORGANIC MATTER, AND, NEAR CONCRETE SURFACES, FREE OF STONES LARGER THAN 3" IN DIAMETER SEE CHARTS FOR DETAILED DESCRIPTIONS OF ACCEPTABLE SOILS.**

- 13.8.5.4. **ZONE C - ZONE C IS THE ROAD SECTION OF GRAVEL, ASPHALT OR CONCRETE BUILT IN COMPLIANCE WITH LOCAL ENGINEERING PRACTICES.**

- 13.8.5.5. **GEOTECHNICAL ENGINEER SHALL REVIEW GRADATIONS OF ALL INTERFACING MATERIALS AND, IF NECESSARY, RECOMMEND GEOTEXTILE FILTER FABRIC (PROVIDED BY CONTRACTOR)**

- 13.8.6. **PLACING AND COMPACTING BACKFILL**
DUMPING FOR BACKFILLING IS NOT ALLOWED ANY NEARER THAN 3'-0" FROM THE BRIDGE LEG.

THE FILL MUST BE PLACED AND COMPACTED IN LAYERS NOT EXCEEDING 8". THE MAXIMUM DIFFERENCE IN THE SURFACE LEVELS OF THE FILL ON OPPOSITE SIDES OF THE BRIDGE MUST NOT EXCEED 2'-0".

THE FILL BEHIND WINGWALLS MUST BE PLACED AT THE SAME TIME AS THAT OF THE BRIDGE FILL. IT MUST BE PLACED IN PROGRESSIVELY PLACED HORIZONTAL LAYERS NOT EXCEEDING 8" PER LAYER.

THE BACKFILL OF ZONE B SHALL BE COMPACTED TO A MINIMUM DENSITY OF 95% OF THE STANDARD PROCTOR, AS REQUIRED BY AASHTO T-99.

SOIL WITHIN 1'-0" OF CONCRETE SURFACES SHALL BE HAND-COMPACTED. ELSEWHERE, USE OF ROLLERS IS ACCEPTABLE. IF VIBRATING ROLLER-COMPACTORS ARE USED, THEY SHALL NOT BE STARTED OR STOPPED WITHIN ZONE B AND THE VIBRATION FREQUENCY SHOULD BE AT LEAST 30 REVOLUTIONS PER SECOND.

THE BACKFILL MATERIAL AND COMPACTING BEHIND WINGWALLS SHALL SATISFY THE CRITERIA FOR THE BRIDGE BACKFILL, ZONE B.

BACKFILL AGAINST A WATERPROOFED SURFACE SHALL BE PLACED CAREFULLY TO AVOID DAMAGE TO THE WATERPROOFING MATERIAL.

- 13.8.7. **BRIDGE UNITS**
FOR FILL HEIGHTS OVER 12 FEET (AS MEASURED FROM TOP CROWN OF BRIDGE TO FINISHED GRADE), NO BACKFILLING MAY BEGIN UNTIL A BACKFILL COMPACTION TESTING PLAN HAS BEEN COORDINATED WITH AND APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

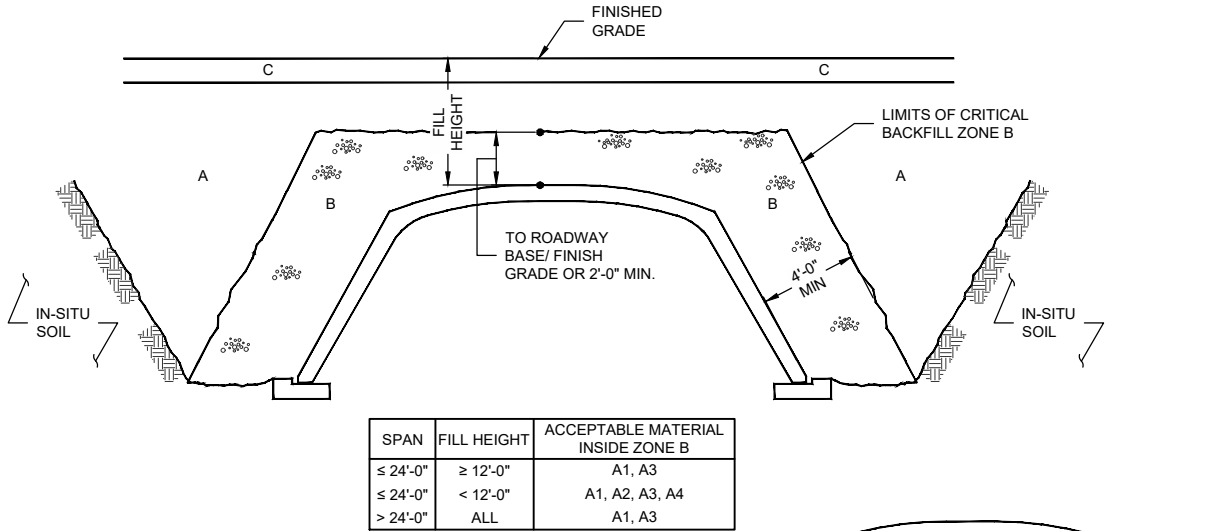
- 13.8.8. **WINGWALLS**
BACKFILL IN FRONT OF WINGWALLS SHALL BE CARRIED TO GROUND LINES SHOWN IN THE PLANS.

- 13.8.9. **MONITORING**
THE CONTRACTOR SHALL CHECK SETTLEMENTS AND HORIZONTAL DISPLACEMENT OF FOUNDATION TO ENSURE THAT THEY ARE WITHIN THE ALLOWABLE LIMIT PROVIDED BY THE ENGINEER. THESE MEASUREMENTS SHOULD GIVE AN INDICATION OF THE SETTLEMENTS AND DEFORMATIONS ALONG THE LENGTH OF THE FOUNDATIONS.

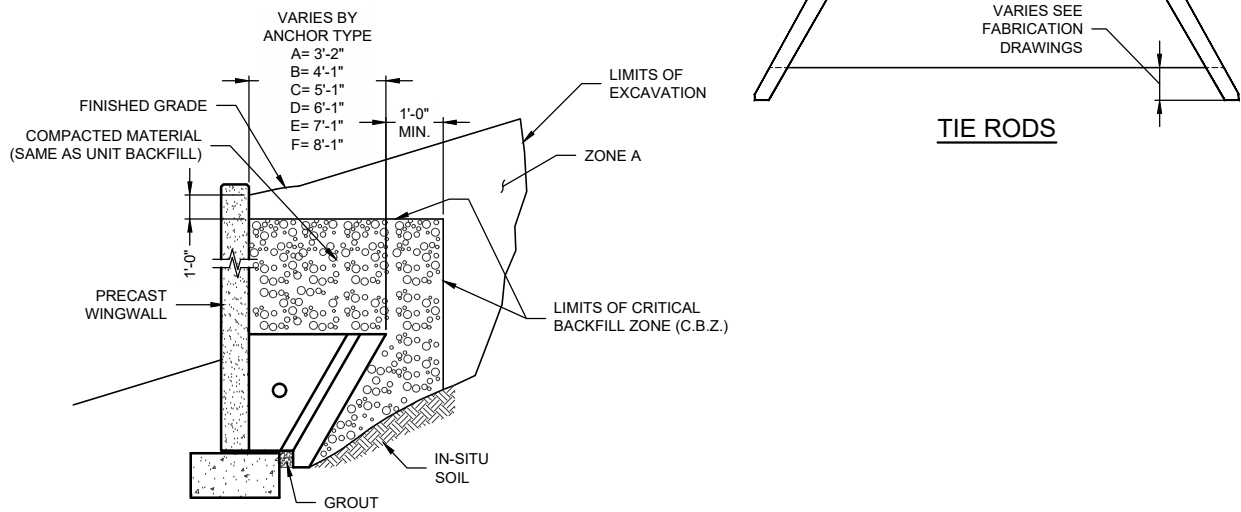
THE FIRST MEASUREMENT SHOULD TAKE PLACE AFTER THE ERECTION OF ALL PRECAST BRIDGE SYSTEM ELEMENTS, A SECOND AFTER COMPLETION OF BACKFILLING, AND A THIRD BEFORE OPENING OF THE BRIDGE TO TRAFFIC. FURTHER MEASUREMENTS MAY BE MADE ACCORDING TO LOCAL CONDITIONS.

ACCEPTABLE SOILS FOR USE IN ZONE B BACKFILL

TYPICAL USCS MATERIALS	AASHTO GROUP	AASHTO SUBGROUP	PERCENT PASSING US SIEVE NO.			CHARACTER OF FRACTION PASSING NO. 40 SIEVE		SOIL DESRIPTION
			#10	#40	#200	LIQUID LIMIT	PLASTICITY INDEX	
GW, GP, SP	A1	A-1a	50 MAX	30 MAX	15 MAX	6 MAX		LARGELY GRAVEL BUT CAN INCLUDE SAND AND FINES GRAVELLY SAND OR GRADED SAND, MAY INCLUDE FINES
GM, SW, SP, SM		A-1b		50 MAX	25 MAX	6 MAX		
GM, SM, ML, SP, GP	A2	A-2-4			35 MAX	40 MAX	10 MAX	SANDS, GRAVELS WITH LOW- PLASTICITY SILT FINES SANDS, GRAVELS WITH PLASTIC SILT FINES
SC, GC, GM		A-2-5			35 MAX	41 MIN	10 MAX	
SP, SM, SW	A3			51 MIN	10 MAX	NON- PLASTIC		FINE SANDS
ML, SM, SC	A4				36 MIN	40 MAX	10 MAX	LOW-COMPRESSIBILTY SILTS



BACKFILL REQUIREMENTS



WALL BACKFILL REQUIREMENTS

CON/SPAN O-SERIES SPECIFICATIONS

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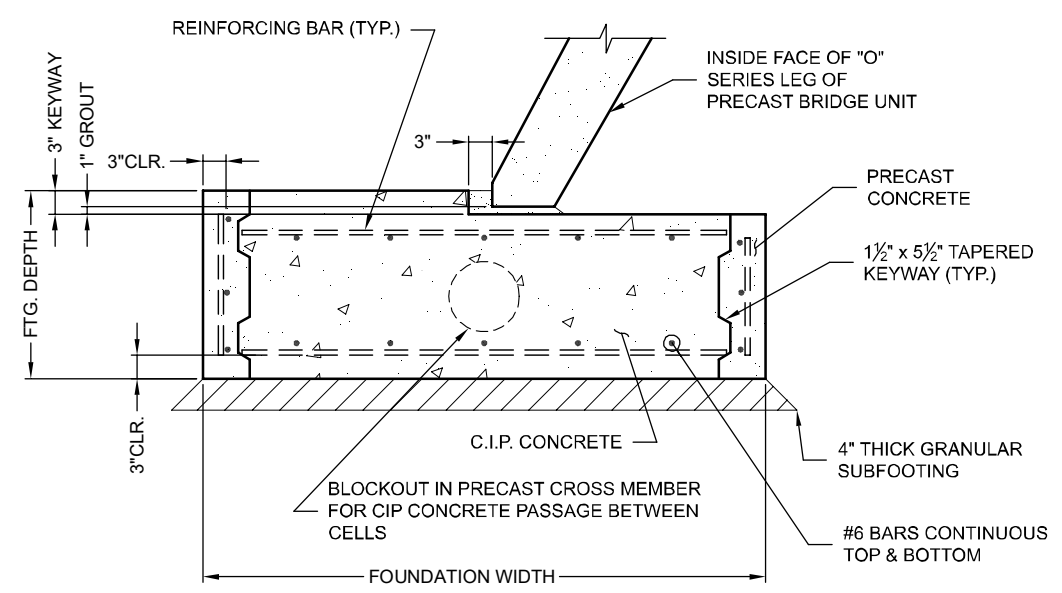
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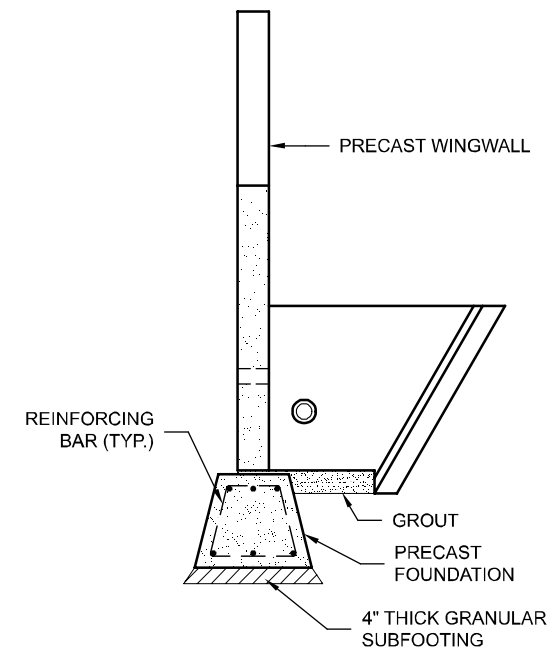
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PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.:	D7 OF D9	

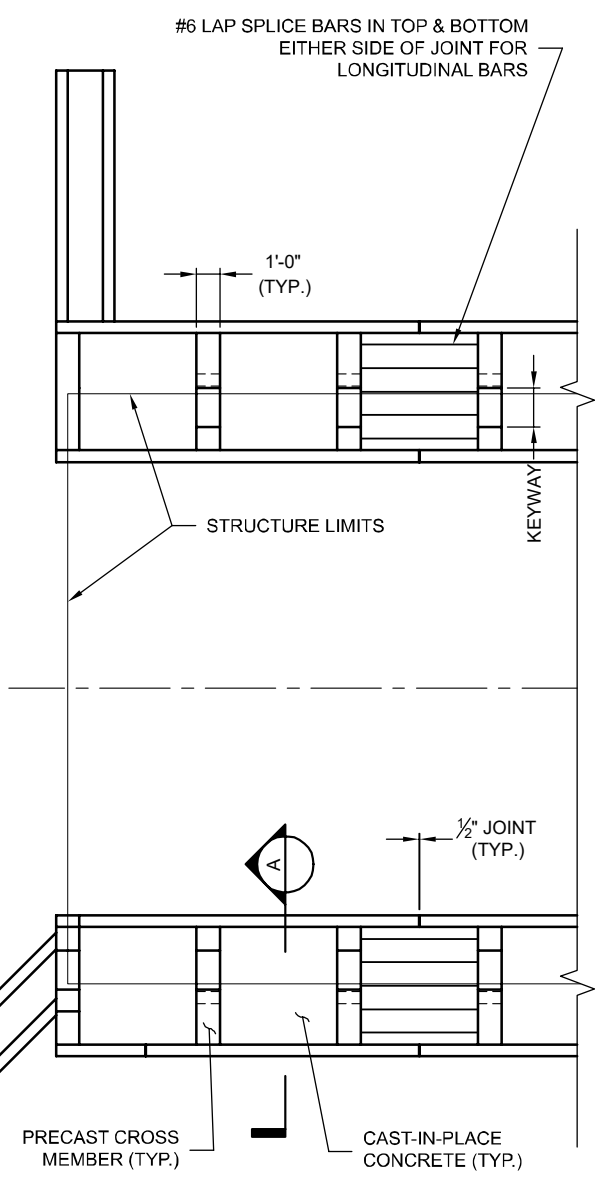
SAMPLE DRAWING ONLY



SECTION A
(NOT PROJECT SPECIFIC)



SECTION B
(NOT PROJECT SPECIFIC)



SAMPLE PARTIAL FOUNDATION PLAN
(NOT PROJECT SPECIFIC)

EXPRESS FOUNDATIONS



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CONSPAN
O-SERIES

DYOB
DRAWING

CON/SPAN O-SERIES
EXPRESS FOUNDATION SAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D8 OF D9

SAMPLE DRAWING ONLY



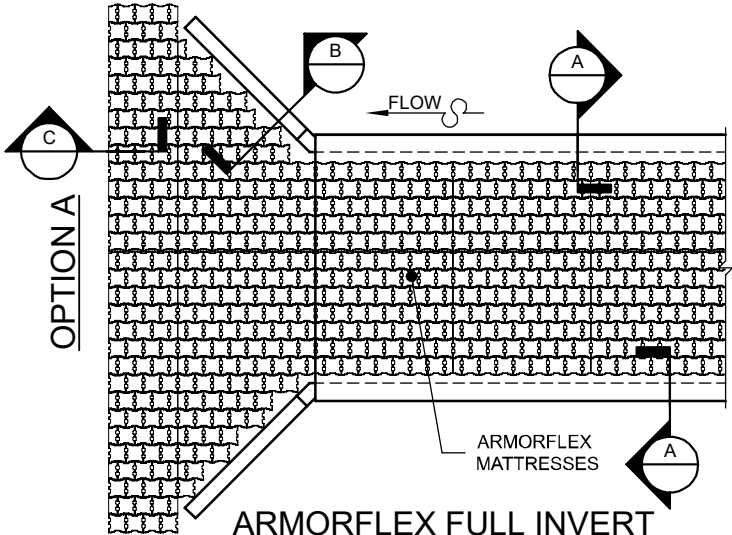
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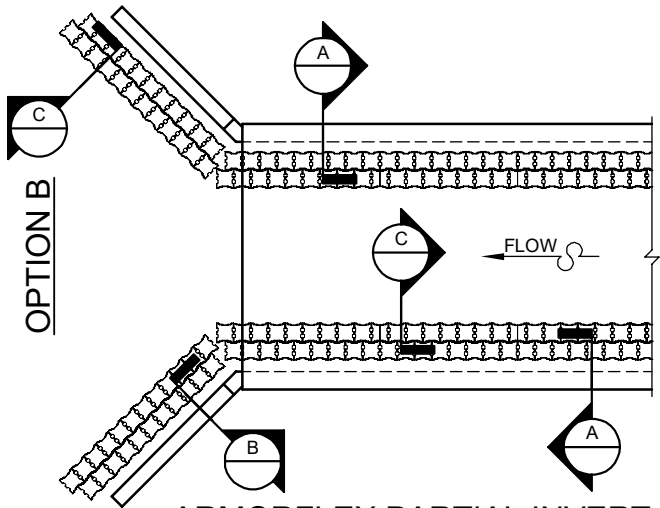
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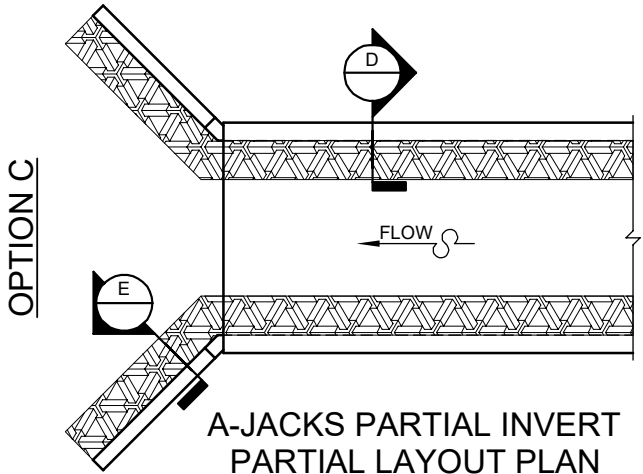
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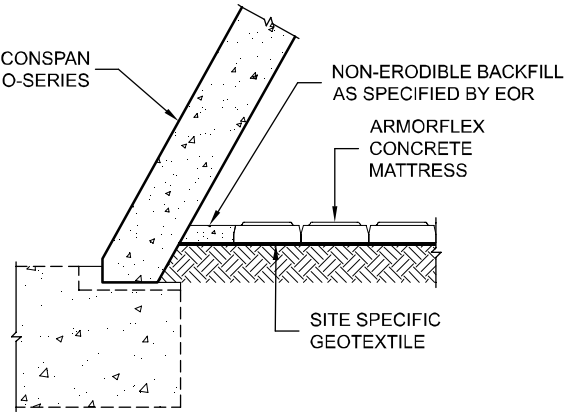


ARMORFLEX PARTIAL INVERT
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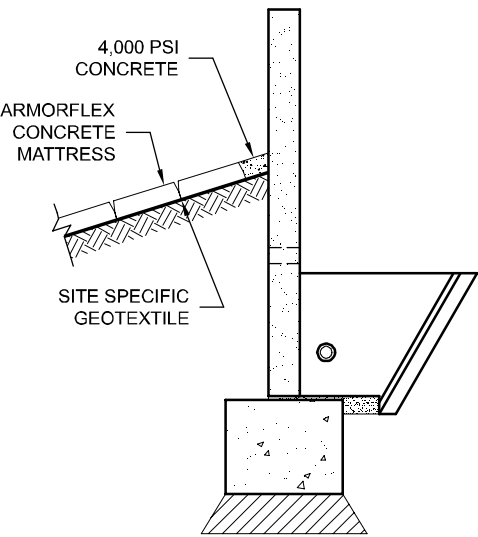


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PARTIAL LAYOUT PLAN
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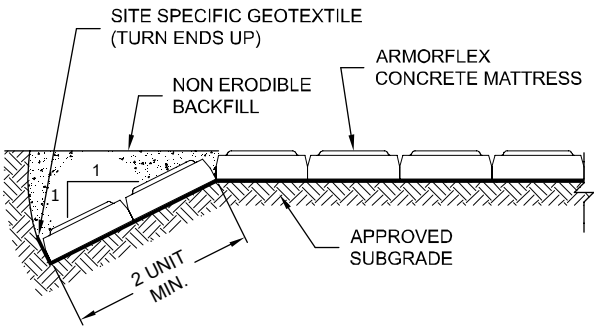
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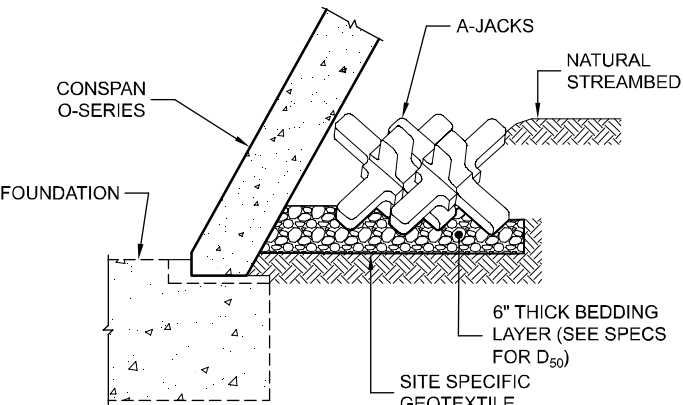
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N.T.S.



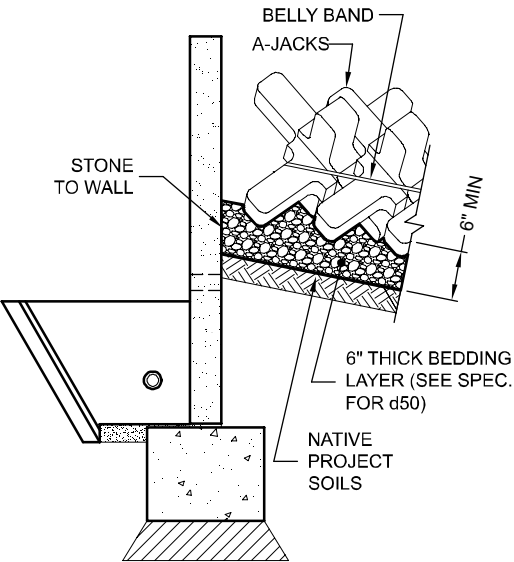
ARMORFLEX WINGWALL
TERMINATION
N.T.S.



STANDARD TERMINATION
N.T.S.



A-JACKS STRUCTURE
TERMINATION
N.T.S.



A-JACKS WINGWALL
TERMINATION
N.T.S.

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CON/SPAN O-SERIES
ARMORTEC EXAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D9 OF D9

PROJECT SUMMARY

LOCAL BRIDGE CONSULTANT

- NAME = Todd Black
- EMAIL = Todd.Black@conteches.com
- PHONE NUMBER = 913-216-3818

STRUCTURE DETAILS

- SPAN = 31'-8"
- RISE = 12'-8"
- LENGTH = 71.50 FT.
- GAGE = 7

FOUNDATIONS

- FOUNDATION TYPE = STRIP

INLET HEADWALL

- INLET HEADWALL TYPE = CAST IN PLACE

OUTLET HEADWALL

- OUTLET HEADWALL TYPE = CAST IN PLACE

WINGWALLS

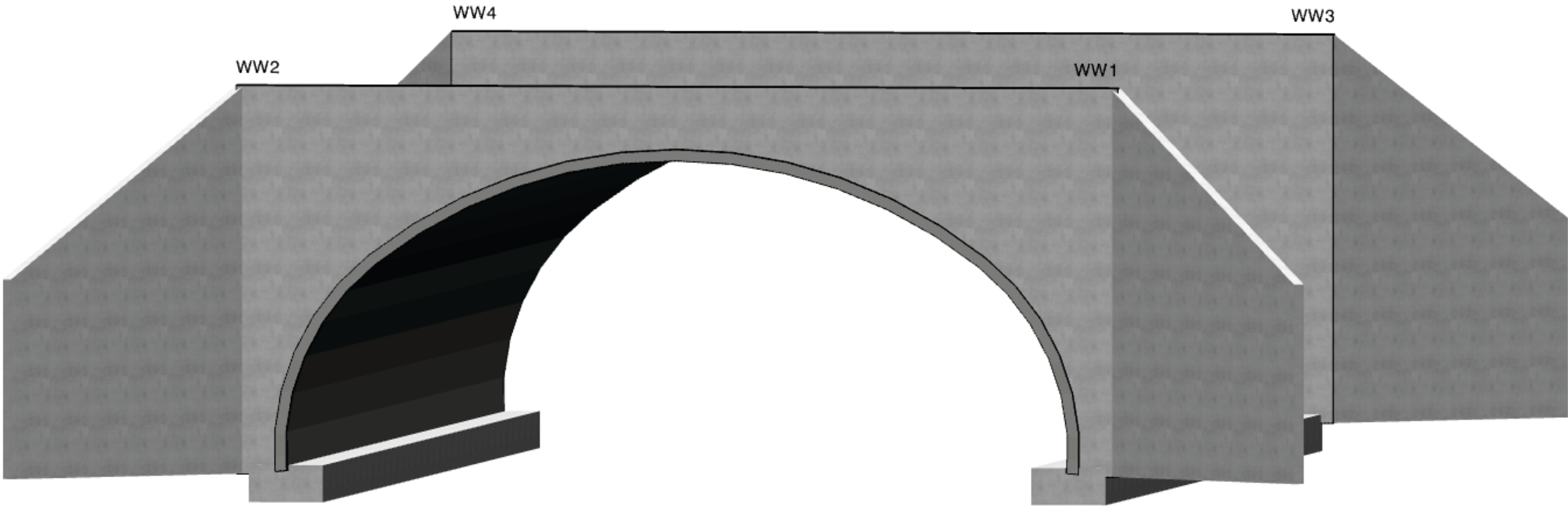
- WW1 ANGLE = 45 DEG.
- WW1 LENGTH = 12 FT.
- WW1 HIGH HEIGHT = 15.67 FT.
- WW1 LOW HEIGHT = 8.00 FT.

- WW2 ANGLE = 45 DEG.
- WW2 LENGTH = 12 FT.
- WW2 HIGH HEIGHT = 15.67 FT.
- WW2 LOW HEIGHT = 8.00 FT.

- WW3 ANGLE = 45 DEG.
- WW3 LENGTH = 12 FT.
- WW3 HIGH HEIGHT = 15.67 FT.
- WW3 LOW HEIGHT = 8.00 FT.

- WW4 ANGLE = 45 DEG.
- WW4 LENGTH = 12 FT.
- WW4 HIGH HEIGHT = 15.67 FT.
- WW4 LOW HEIGHT = 8.00 FT.
- CAST IN PLACE HEADWALLS AND WINGWALLS ARE TO BE SUPPLIED BY OTHERS THAN CONTECH.

BRIDGECOR TWO RADIUS ARCH DYO
BC 2RA



NOTES

1. THIS BRIDGE HAS BEEN DESIGNED FOR GENERAL SITE CONDITIONS. THE PROJECT ENGINEER SHALL BE RESPONSIBLE FOR THE STRUCTURE'S SUITABILITY TO THE EXISTING SITE CONDITIONS AND FOR THE HYDRAULIC EVALUATION -- INCLUDING SCOUR AND CONFIRMATION OF SOIL CONDITIONS.
2. PRIOR TO CONSTRUCTION, CONTRACTOR MUST VERIFY ALL ELEVATIONS SHOWN THROUGH THE ENGINEER.
3. ONLY CONTECH ENGINEERED SOLUTIONS LLC, THE BRIDGECOR APPROVED MANUFACTURER IN THE PROJECT STATE, MAY PROVIDE THE STRUCTURE DESIGNED IN ACCORDANCE WITH THESE PLANS.
4. THIS DYOБ DRAWING IS A CONCEPTUAL DESIGN. PLEASE WORK WITH YOUR LOCAL BRIDGE CONSULTANT FOR FURTHER SOLUTION DEVELOPMENT AND PRICING.

PRELIMINARY
NOT FOR CONSTRUCTION

DYO89598 WILDLIFE UNDERPASS MP 73.6

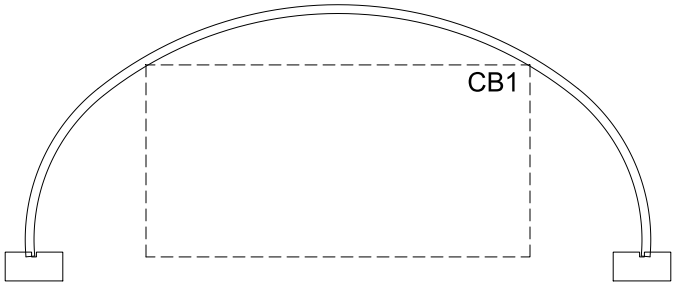
BC 2RA

PRICE,UT

BRIDGECOR TWO RADIUS ARCH 31'-8" SPAN X 12'-8" RISE

65294	89598	10/20/2025
DYO		DYO
DYO		DYO
D1		D9

CB1 Clearance Height: 10 (ft.)
CB1 Clearance Width: 20 (ft.)



CROSS SECTION

PRELIMINARY
NOT FOR CONSTRUCTION

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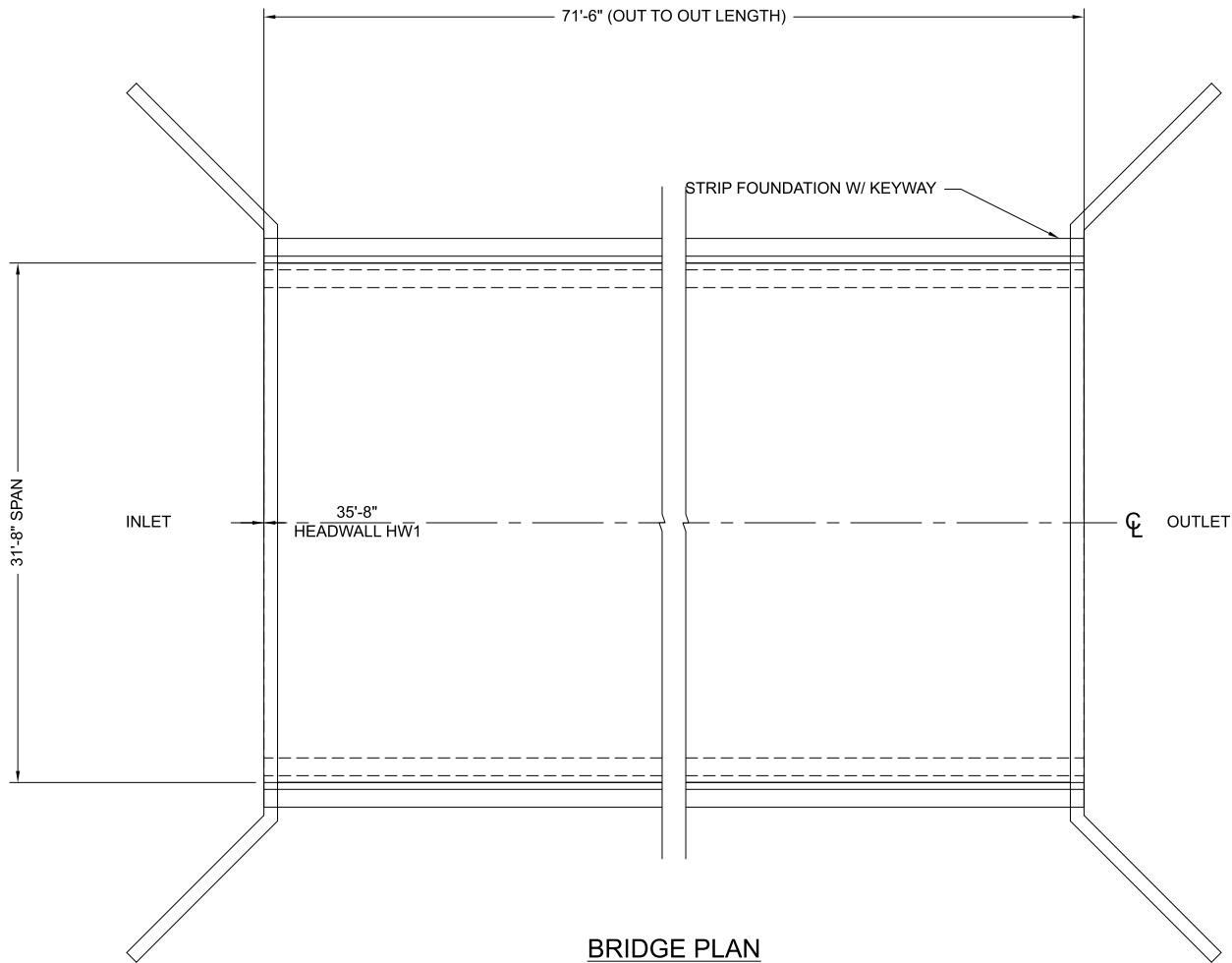
DYO89598 WILDLIFE UNDERPASS MP 73.6

BC 2RA

PRICE,UT

BRIDGECOR TWO RADIUS ARCH 31'-8" SPAN X 12'-8" RISE

65294	89598	10/20/2025
DYO		DYO
DYO		DYO
D2		D9



PRELIMINARY
NOT FOR CONSTRUCTION

DYO89598 WILDLIFE UNDERPASS MP 73.6

BC 2RA

PRICE,UT

BRIDGECOR TWO RADIUS ARCH 31'-8" SPAN X 12'-8" RISE

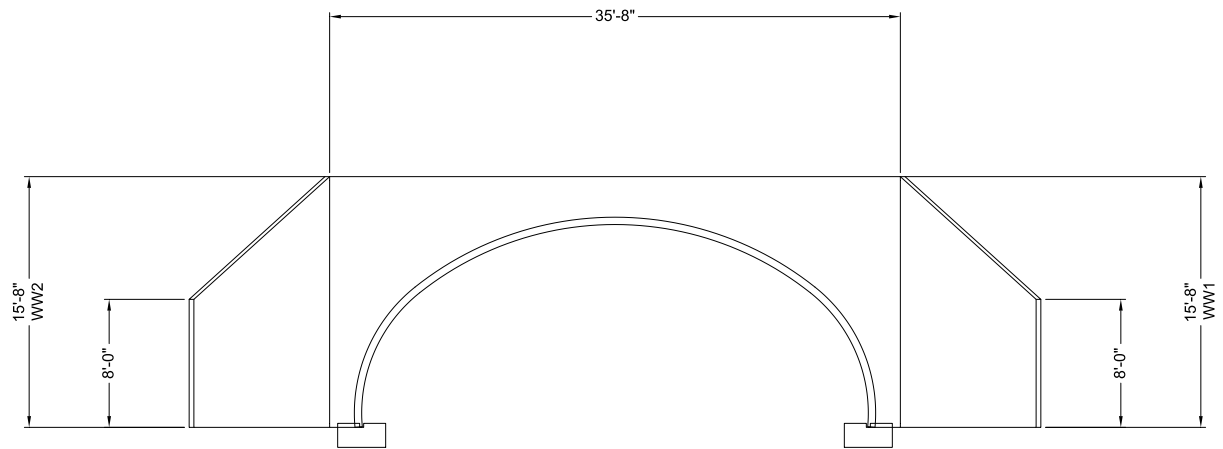
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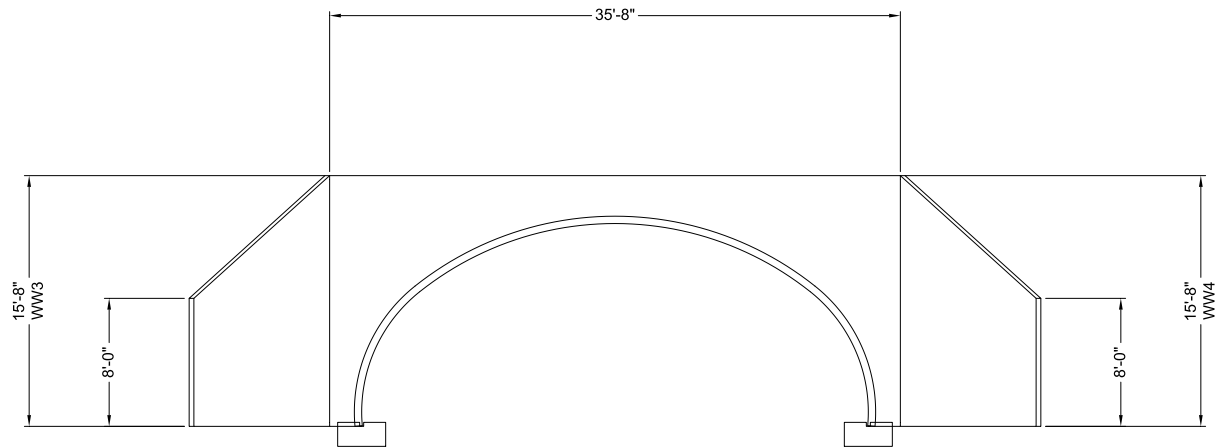
DYO DYO

D3 D9

* CONCRETE HEADWALLS AND WINGWALLS PROVIDED BY OTHERS



INLET END ELEVATION



OUTLET END ELEVATION

PRELIMINARY
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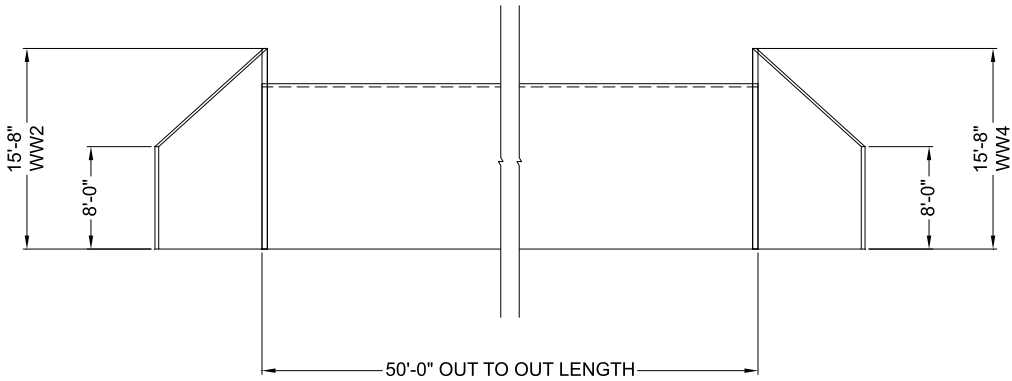
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BC 2RA

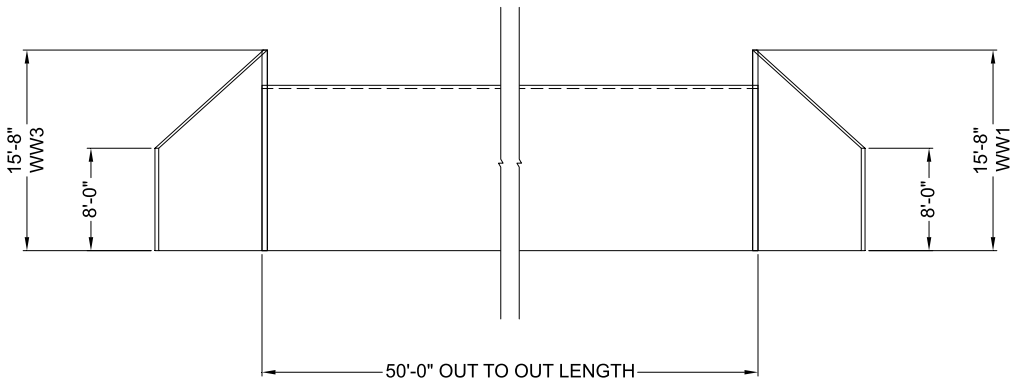
PRICE,UT

BRIDGECOR TWO RADIUS ARCH 31'-8" SPAN X 12'-8" RISE

65294	89598	10/20/2025
DYO		DYO
DYO		DYO
D4		D9



PROFILE



PROFILE

PRELIMINARY
NOT FOR CONSTRUCTION

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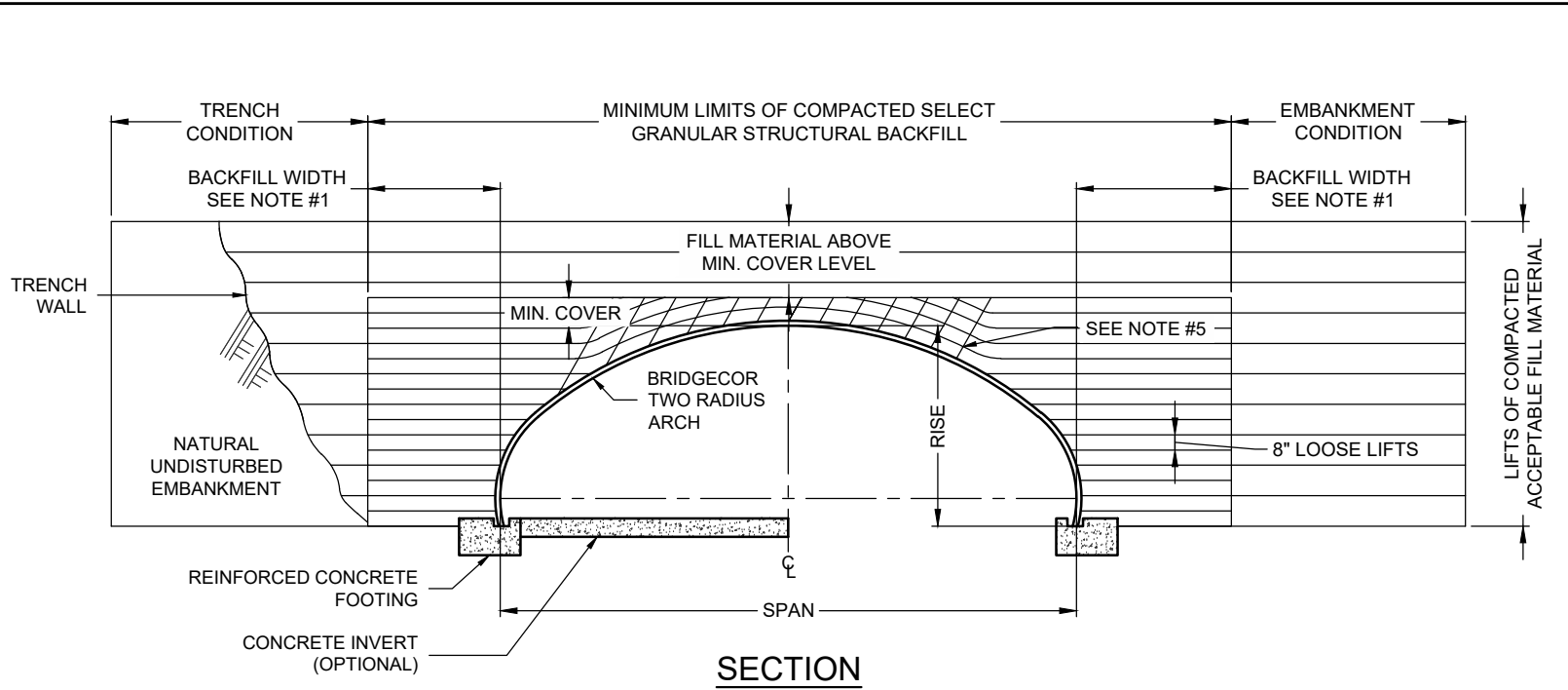
DYO89598 WILDLIFE UNDERPASS MP 73.6

BC 2RA

PRICE,UT

BRIDGECOR TWO RADIUS ARCH 31'-8" SPAN X 12'-8" RISE

65294	89598	10/20/2025
DYO		DYO
DYO		DYO
D5		D9



SECTION

-
- SELECT GRANULAR STRUCTURAL BACKFILL LIMITS.
-
- INITIAL LIFTS OVER THE CROWN OF STRUCTURE AS INDICATED BY SHADED AREA TO BE COMPACTED TO REQUIRED DENSITY WITH HAND OPERATED EQUIPMENT OR WITH LIGHTWEIGHT TRACTOR (D-4 OR LIGHTER) EQUIPMENT.

- NOTES:**
- MINIMUM SELECT GRANULAR STRUCTURAL BACKFILL WIDTH IS BASED ON AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS SECTION 12 AND/OR THE RESULTS OF THE PROJECT SPECIFIC FINITE ELEMENT ANALYSIS.
 - ALL SELECT GRANULAR STRUCTURAL BACKFILL TO BE PLACED IN A BALANCED FASHION IN THIN LIFTS (8" LOOSE TYPICALLY) AND COMPACTED TO 90 PERCENT DENSITY PER AASHTO T-180.
 - MONITORING OF THE TWO RADIUS ARCH STRUCTURE IS REQUIRED DURING THE BACKFILLING PROCESS. THE METHOD, FREQUENCY AND DURATION SHALL BE DETERMINED BASED ON THE SIZE AND SHAPE OF THE STRUCTURE.
 - PREVENT DISTORTION OF SHAPE AS NECESSARY BY VARYING COMPACTION METHODS AND EQUIPMENT.
 - PLACE SELECT GRANULAR STRUCTURAL BACKFILL IN RADIAL LIFTS AT APPROXIMATELY 75% OF THE RISE OF THE TWO RADIUS ARCH STRUCTURE.
 - BECAUSE OF THE FLEXING AND VIBRATION OF THE CROWN PLATES, THE FULL COMPACTION DENSITY LEVELS OFTEN CAN NOT BE ACHIEVED IN THE FIRST SEVERAL INCHES OF FILL OVER THE CROWN.

- ADDITIONAL SELECT GRANULAR STRUCTURAL BACKFILL NOTES:
- SATISFACTORY BACKFILL MATERIAL, PROPER PLACEMENT, AND COMPACTION ARE KEY FACTORS IN OBTAINING MAXIMUM STRENGTH AND STABILITY.
- THE BACKFILL MATERIAL SHOULD BE FREE OF ROCKS, FROZEN LUMPS, AND FOREIGN MATERIAL THAT COULD CAUSE HARD SPOTS OR DECOMPOSE TO CREATE VOIDS. BACKFILL MATERIAL SHOULD BE WELL GRADED GRANULAR MATERIAL THAT MEETS THE REQUIREMENTS OF AASHTO M-145 FOR SOIL CLASSIFICATIONS A-1, A-2-4, A-2-5 OR A-3 MODIFIED. RECYCLED CONCRETE/SLAG ARE NOT RECOMMENDED FOR STRUCTURAL BACKFILL MATERIAL. (DEPENDING ON THE SIZE AND SHAPE OF THE STRUCTURE; SPECIFIC BACKFILLS MAY BE REQUIRED). SEE THE STRUCTURAL PLATE BACKFILL GROUP CLASSIFICATION ON THIS SHEET. BACKFILL MUST BE PLACED SYMMETRICALLY ON EACH SIDE OF THE STRUCTURE IN 8" LOOSE LIFTS. EACH LIFT IS TO BE COMPACTED TO A MINIMUM OF 90% DENSITY PER AASHTO T-180.
- A HIGH PERCENTAGE OF SILT OR FINE SAND IN THE NATIVE SOILS SUGGESTS THE NEED FOR A WELL GRADED GRANULAR BACKFILL MATERIAL TO PREVENT SOIL MIGRATION. IF THE PROPOSED BACKFILL IS NOT A WELL GRADED GRANULAR MATERIAL, A NON-WOVEN GEOTEXTILE FILTER FABRIC SHALL BE PLACED BETWEEN THE SELECT BACKFILL AND THE IN SITU MATERIAL.
- DURING BACKFILL, ONLY LIGHTWEIGHT TRACKED VEHICLES (D-4 OR LIGHTER) SHOULD BE NEAR THE STRUCTURE AS FILL PROGRESSES ABOVE THE CROWN AND TO THE FINISHED GRADE. THE ENGINEER AND CONTRACTOR ARE CAUTIONED THAT THE MINIMUM COVER MAY NEED TO BE INCREASED TO HANDLE TEMPORARY CONSTRUCTION VEHICLE LOADS (HEAVIER THAN D-4).

STRUCTURAL PLATE BACKFILL GROUP CLASSIFICATION, REFERENCE AASHTO M-145					
GROUP CLASSIFICATION	A-1-a	A-1-b	A-2-4	A-2-5	A-3
Sieve Analysis Percent Passing					
No. 10 (2,000 mm)	50 max.	----	----	----	----
No. 40 (0.425 mm)	30 max.	50 max.	----	----	51 max.*
No. 200 (0.075 mm)	15 max.	25 max.	35 max.	35 max.	10 max.
Atterberg Limits for Fraction Passing No. 40 (0.425 mm)					
Liquid Limits	----	----	40 max.	41 min.	----
Plasticity Index	6 max.	6 max.	10 max.	10 max.	Non Plastic
Usual Materials	Stone Fragment, Gravel and Sand		Silty or Clayey Gravel and Sand		Coarse Sand

*Modified from AASHTO M-145.

Fine beach sands, windblown sands, stream deposited sands, etc., exhibiting fine, rounded particles and typically classified by AASHTO M-145 as A-3 Materials should not be used.

If 95% Compaction per AASHTO T-180 is specified, the backfill material shall be a A-1-a.

Reference the most current version of ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) for comparable soil groups.

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CONTECH
STRUCTURAL PLATE

DYOB
DRAWING

- 1.0 **STANDARDS AND DEFINITIONS**
- 1.1 STANDARDS - All standards refer to the current ASTM/AASHTO edition unless otherwise noted.
- 1.1.1 ASTM A761 "Corrugated Steel Structural Plate, Zinc Coated for Field-Bolted Pipe, Pipe-Arches and Arches" (AASHTO Designation M-167).
- 1.1.2 AASHTO Standard Specification for Highway Bridges - Section 12 Division I - Design, AASHTO LRFD Bridge Design Specifications Section 12.
- 1.1.3 AASHTO Standard Specification for Highway Bridges - Section 26 Division II - Construction, AASHTO LRFD Bridge Construction Specifications - Section 26. ASTM A807, Standard Practice for Installing Corrugated Steel Structural Plate Pipe.
- 1.2 **DEFINITIONS**
- 1.2.1 Owner - In these specifications the word "Owner" shall mean #####.
- 1.2.2 Engineer - In these specifications the word "Engineer" shall mean the Engineer of Record or Owner's designated engineering representative.
- 1.2.3 Manufacturer - In these specifications the word "Manufacturer" shall mean CONTECH ENGINEERED SOLUTIONS 800-338-1122 #####.
- 1.2.4 Contractor - In these specifications the word "Contractor" shall mean the firm or corporation undertaking the execution of any installation work under the terms of these specifications.
- 1.2.5 Approved - In these specifications the word "approved" shall refer to the approval of the Engineer or his designated representative.
- 1.2.6 As Directed - In these specifications the words "as directed" shall refer to the directions to the Contractor from the Owner or his designated representative.
- 2.0 **GENERAL CONDITIONS**
- 2.1 Any installation provided herein shall be endorsed by the Engineer; discrepancies herein are governed by the Engineer's plans and specifications.
- 2.2 The Contractor shall furnish all labor, material and equipment and perform all work and services except those set out and furnished by the Owner, necessary to complete in a satisfactory manner the site preparation, excavation, filling, compaction, grading as shown on the plans and as described therein. This work shall consist of all mobilization clearing and grading, grubbing, stripping, removal of existing material unless otherwise stated, preparation of the land to be filled, filling of the land, spreading and compaction of the fill, and all subsidiary work necessary to complete the grading of the cut and fill areas to conform with the lines, grades, slopes, and specifications. This work is to be accomplished under the observation of the Owner or his designated representative.
- 2.3 Prior to bidding the work, the Contractor shall examine, investigate and inspect the construction site as to the nature and location of the work, and the general and local conditions at the construction site, including without limitation, the character of surface or subsurface conditions and obstacles to be encountered on and around the construction site and shall make such additional investigation as he may deem necessary for the planning and proper execution of the work.
- If conditions other than those indicated are discovered by the Contractor, the Owner shall be notified immediately. The material which the Contractor believes to be a changed condition shall not be disturbed so that the owner can investigate the condition.
- 2.4 The construction shall be performed under the direction of the Engineer.
- 2.5 All aspects of the structure design and site layout including foundations, backfill, end treatments and necessary scour consideration shall be performed by the Engineer.

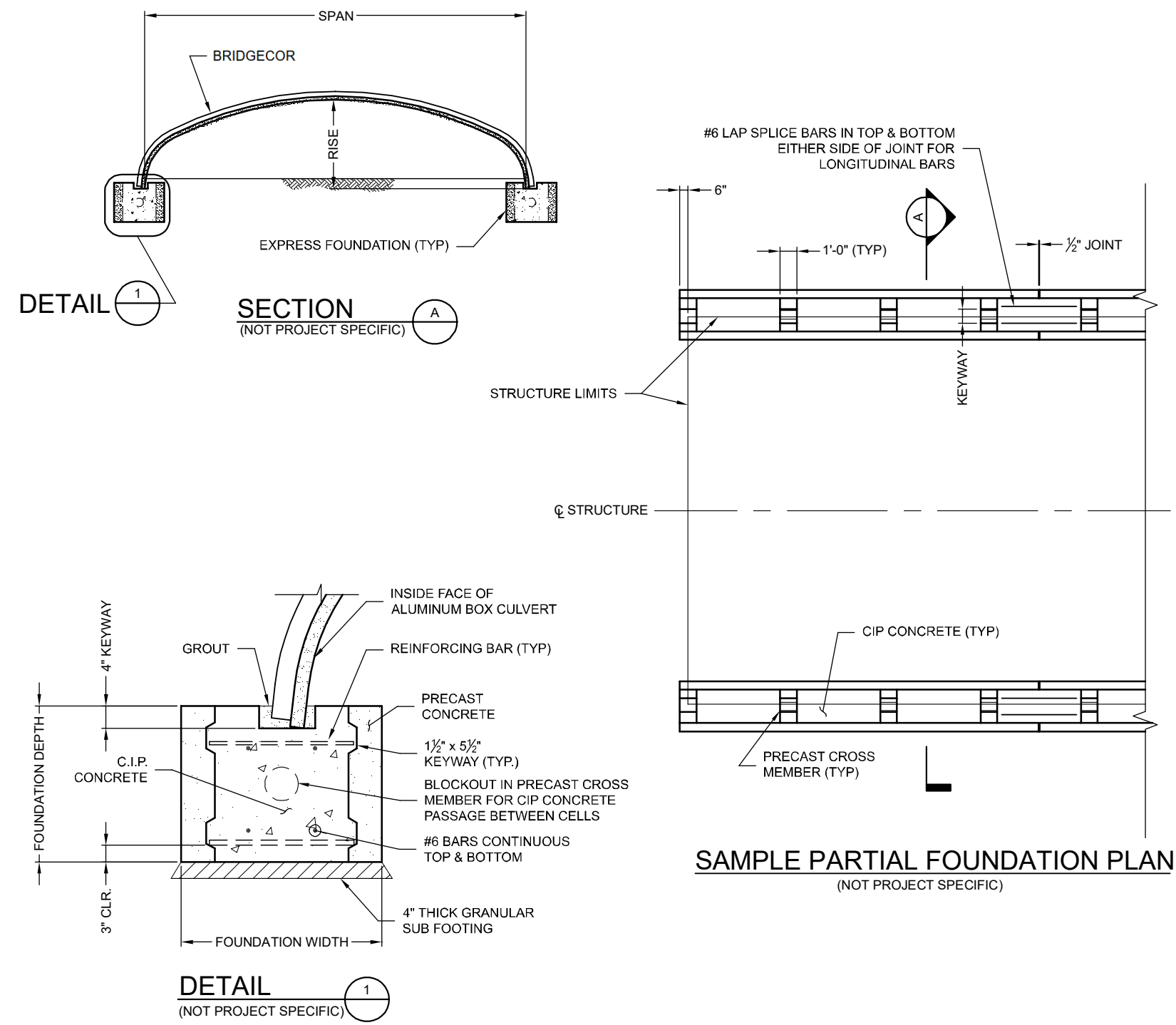
- 3.0 **ASSEMBLY AND INSTALLATION**
- 3.1 Bolts and nuts shall conform to the requirements of ASTM A449. The two radius arch structure shall be assembled in accordance with the plate layout drawings provided by the Manufacturer and per the Manufacturer's recommendations.
- Bolts shall be tightened using an applied torque of between 100 and 300 ft.-lbs.
- 3.2 The two radius arch structure shall be installed in accordance with the plans and specifications, the Manufacturer's recommendations, and AASHTO Standard Specification for Highway Bridges - Section 26 Division II - Construction/AASHTO LRFD Bridge Construction Specifications - Section 26.
- 3.3 Trench excavation shall be made in embankment material that is structurally adequate. The trench width shall be shown on the plans. Poor quality in situ embankment material must be removed and replaced with suitable backfill as directed by the Engineer.
- 3.4 Bedding preparation is critical to both structure performance and service life. The bed should be constructed to uniform line and grade to avoid distortions that may create undesirable stresses in the structure and/or rapid deterioration of the roadway. The bed should be free of rock formations, protruding stones, frozen lumps, roots, and other foreign matter that may cause unequal settlement.
- 3.5 The structure shall be assembled in accordance with the Manufacturer's instructions. All plates shall be unloaded and handled with reasonable care. Plates shall not be rolled or dragged over gravel rock and shall be prevented from striking rock or other hard objects during placement in trench or on bedding.
- 3.6 The structure shall be backfilled using clean well graded granular material that meets the requirements for soil classifications A-1, A-2-4, A-2-5 or A-3 modified per AASHTO M-145. See the structural plate backfill group classification table on this sheet.
- Backfill must be placed symmetrically on each side of the structure in 8 inch loose lifts. Each lift shall be compacted to a minimum of 90 percent density per AASHTO T-180.
- 3.7 If temporary construction vehicles are required to cross the structure, it is the Contractor's responsibility to contact the Engineer to determine the amount of additional minimum cover necessary to handle the specific loading condition.
- Normal highway traffic is not allowed to cross the structure until the structure has been backfilled and paved. If the road is unpaved, cover allowance to accommodate rutting shall be as directed by the Engineer.
- 3.8 If a metal headwall and/or wingwall system is specified, the select granular structural backfill limits shall extend past the deadman anchor system. Contact the Engineer if stiff material or rock is encountered where the wingwalls and deadmen are to be installed.

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MARK	DATE	REVISION DESCRIPTION	BY

BRIDGECOR
SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.: D7 OF D9		

SAMPLE DRAWING ONLY



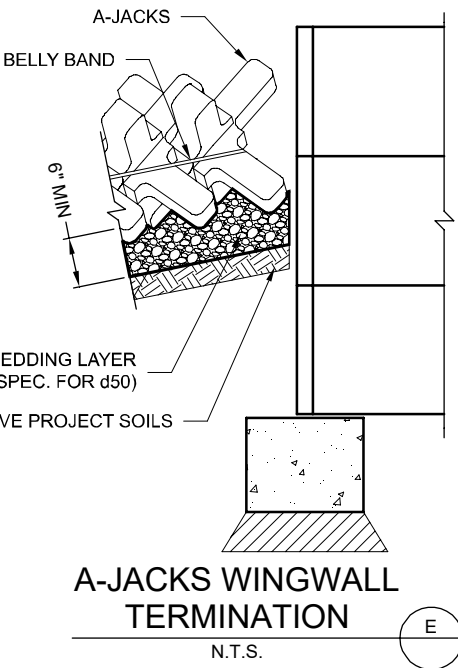
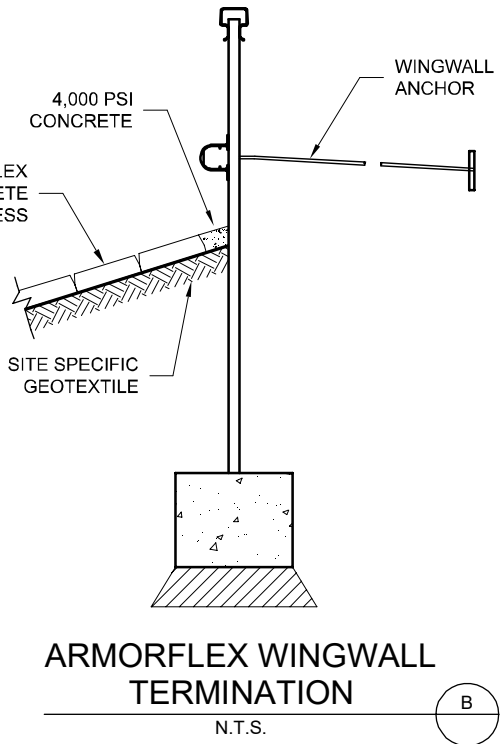
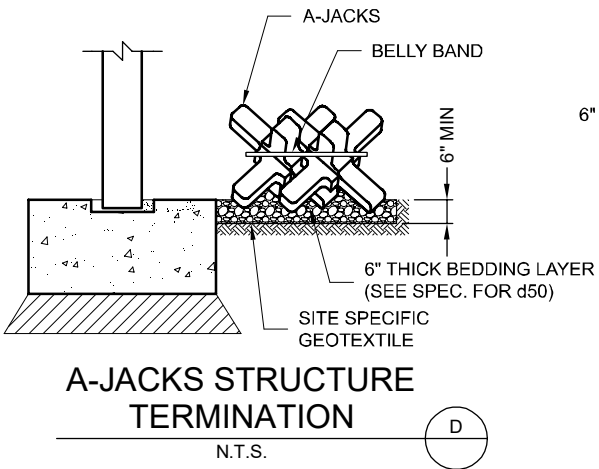
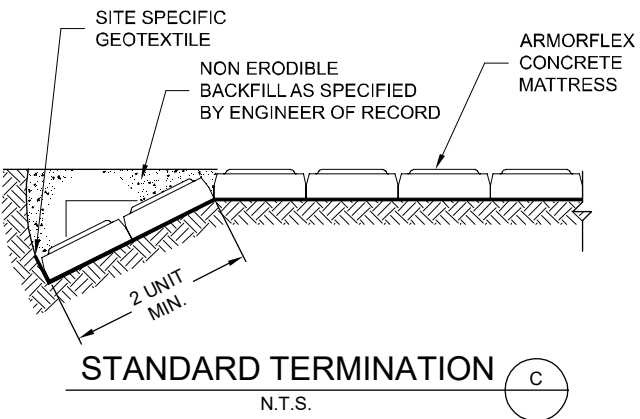
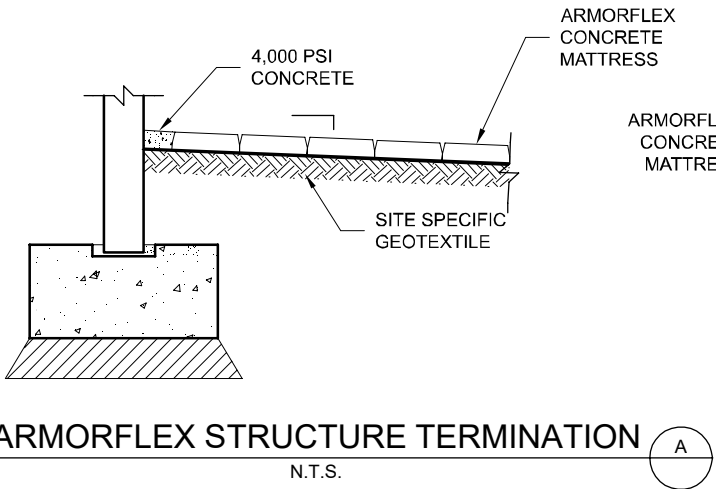
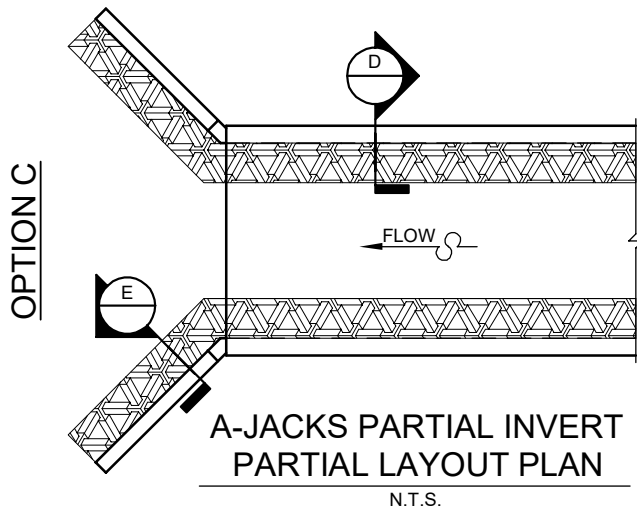
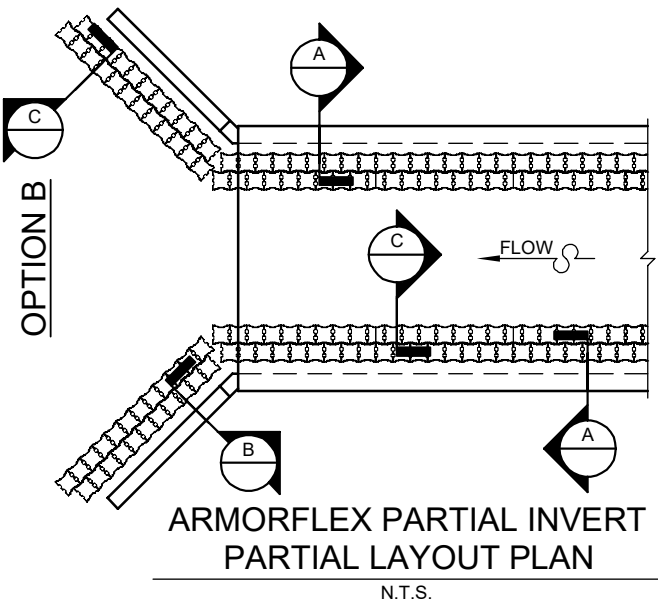
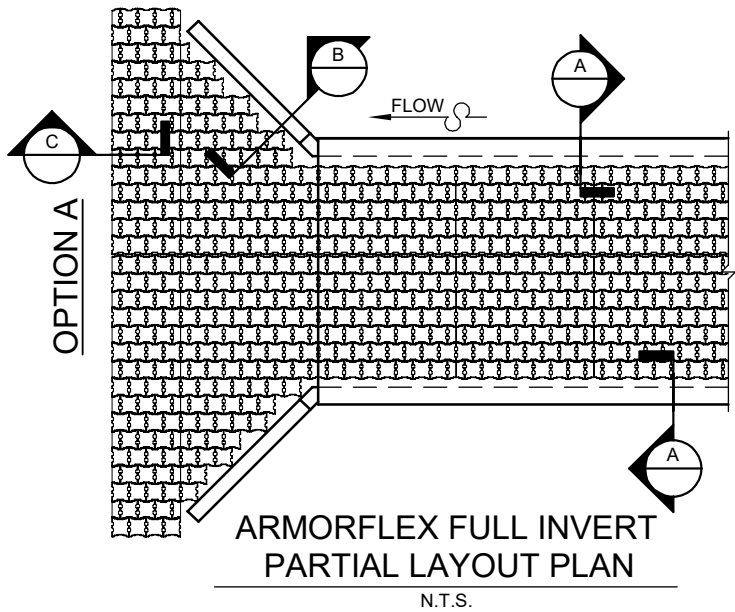
EXPRESS FOUNDATIONS



SAMPLE DRAWING ONLY



A-JACKS PARTIAL INVERT
N.T.S.



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800-338-1122 513-645-7000 513-645-7993 FAX

DYOB
DRAWING

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.: D9 OF D9	

PROJECT SUMMARY

LOCAL BRIDGE CONSULTANT

- NAME = Todd Black
- EMAIL = Todd.Black@conteches.com
- PHONE NUMBER = 913-216-3818

STRUCTURE DETAILS

- SPAN = 32' - 0"
- PRECAST RISE = 11' - 0 3/4"
- LENGTH = 70 FT.

HEADWALLS

- INLET HEADWALL HEIGHT = 2 FT.
- OUTLET HEADWALL HEIGHT = 2 FT.

FOUNDATIONS

- FOUNDATION TYPE = STRIP

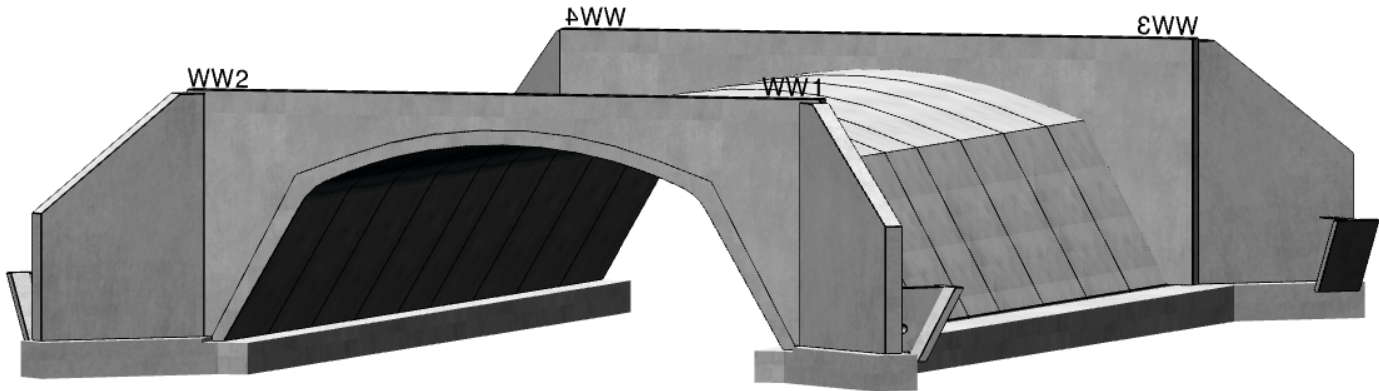
WINGWALLS

- WW 1 ANGLE = 45 DEG.
- WW 1 LENGTH = 10 FT.
- WW 1 HIGH HEIGHT = 13.4 FT.
- WW 1 LOW HEIGHT = 7 FT.
- WW 2 ANGLE = 45 DEG.
- WW 2 LENGTH = 10 FT.
- WW 2 HIGH HEIGHT = 13.4 FT.
- WW 2 LOW HEIGHT = 7 FT.
- WW 3 ANGLE = 45 DEG.
- WW 3 LENGTH = 10 FT.
- WW 3 HIGH HEIGHT = 13.4 FT.
- WW 3 LOW HEIGHT = 7 FT.
- WW 4 ANGLE = 45 DEG.
- WW 4 LENGTH = 10 FT.
- WW 4 HIGH HEIGHT = 13.4 FT.
- WW 4 LOW HEIGHT = 7 FT.

NOTES

1. THIS BRIDGE HAS BEEN DESIGNED FOR GENERAL SITE CONDITIONS. THE PROJECT ENGINEER SHALL BE RESPONSIBLE FOR THE STRUCTURE'S SUITABILITY TO THE EXISTING SITE CONDITIONS AND FOR THE HYDRAULIC EVALUATION -- INCLUDING SCOUR AND CONFIRMATION OF SOIL CONDITIONS.
2. PRIOR TO CONSTRUCTION, CONTRACTOR MUST VERIFY ALL ELEVATIONS SHOWN THROUGH THE ENGINEER.
3. ONLY CONTECH ENGINEERED SOLUTIONS LLC, THE CONSPAN APPROVED MANUFACTURER IN THE PROJECT STATE MAY PROVIDE THE STRUCTURE DESIGNED IN ACCORDANCE WITH THESE PLANS.
4. THIS DYOB DRAWING IS A CONCEPTUAL DESIGN. PLEASE WORK WITH YOUR LOCAL BRIDGE CONSULTANT FOR FURTHER SOLUTION DEVELOPMENT AND PRICING.
5. THE USE OF ANOTHER PRECAST STRUCTURE WITH THE DESIGN ASSUMPTIONS USED FOR THE CON/SPAN® STRUCTURE MAY LEAD TO SERIOUS DESIGN ERRORS. USE OF ANY OTHER PRECAST STRUCTURE WITH THIS DESIGN AND DRAWINGS VOIDS ANY CERTIFICATION OF THIS DESIGN AND WARRANTY. CONTECH ENGINEERED SOLUTIONS ASSUMES NO LIABILITY FOR DESIGN OF ANY ALTERNATE OR SIMILAR TYPE STRUCTURES.

CON/SPAN O-Series DYOB
Conspan O



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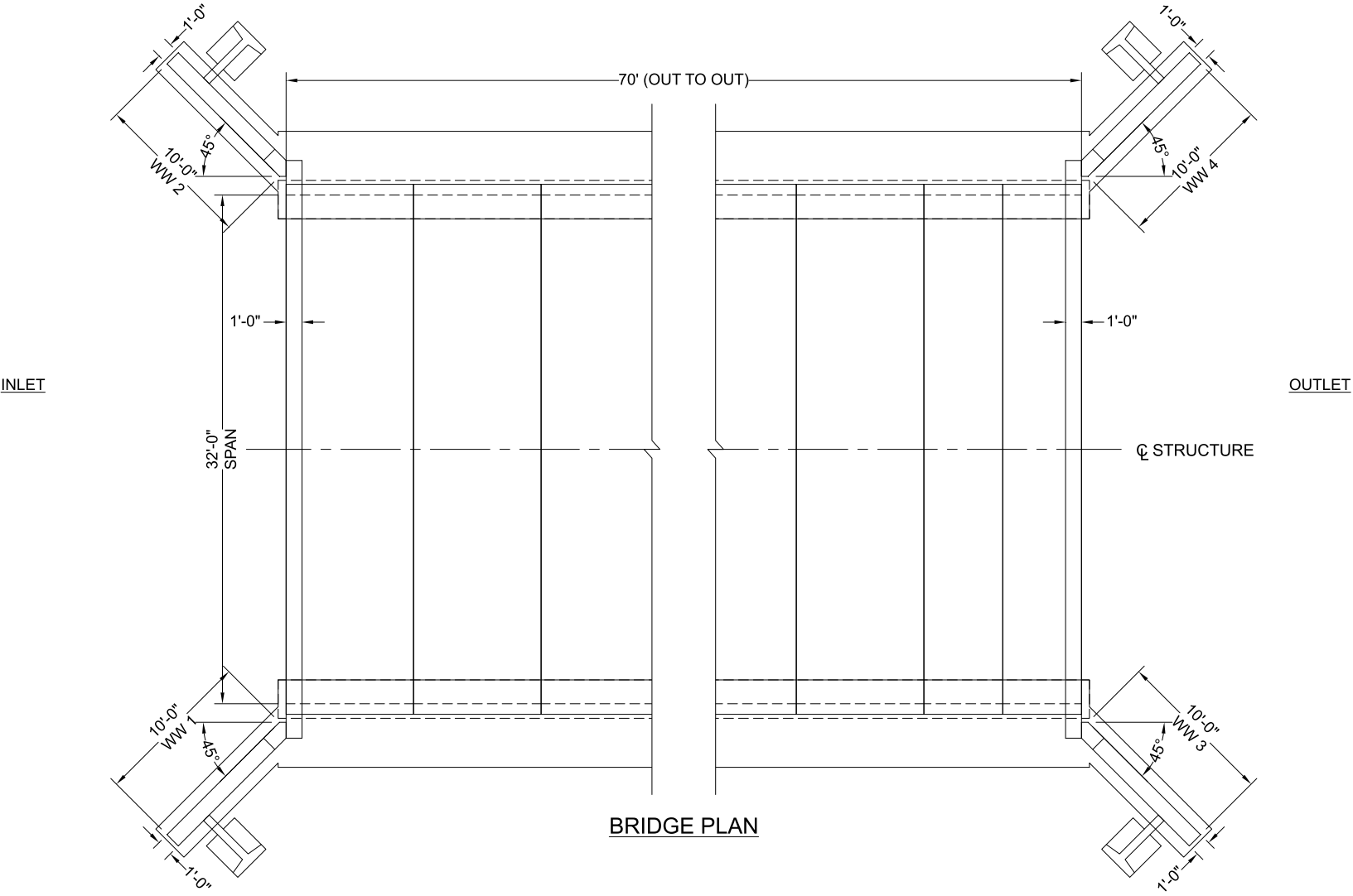
CON/SPAN

O-SERIES

DYOB
DRAWING

DYO89508, Wildlife Underpass MP 73.6
Conspan O
Price, UT
O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65294	DYO No.: 89508	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D1 OF D9		



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CONSPAN

SERIES

DYOB
DRAWING

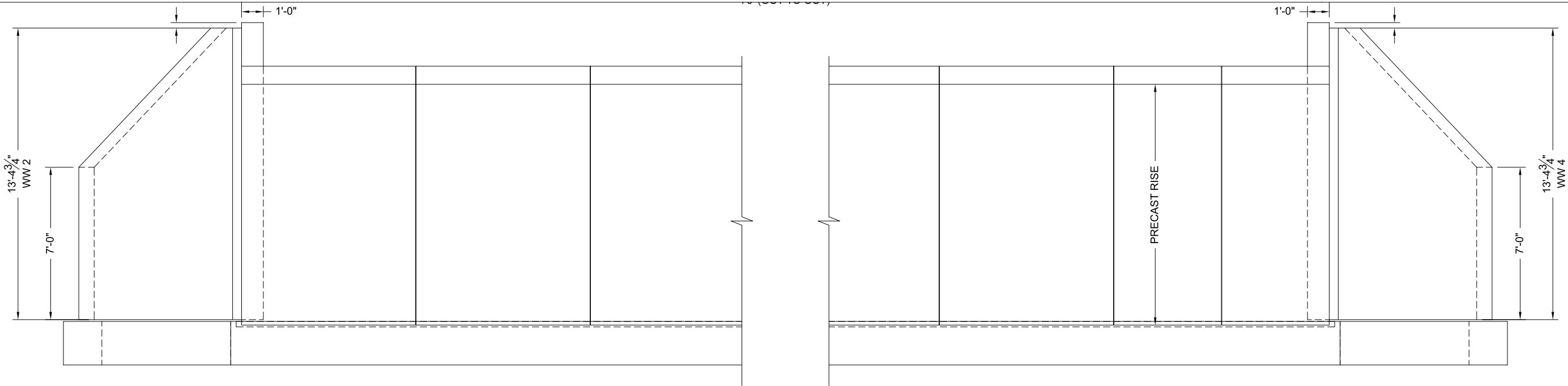
DYO89508, Wildlife Underpass MP 73.6

Conspan O

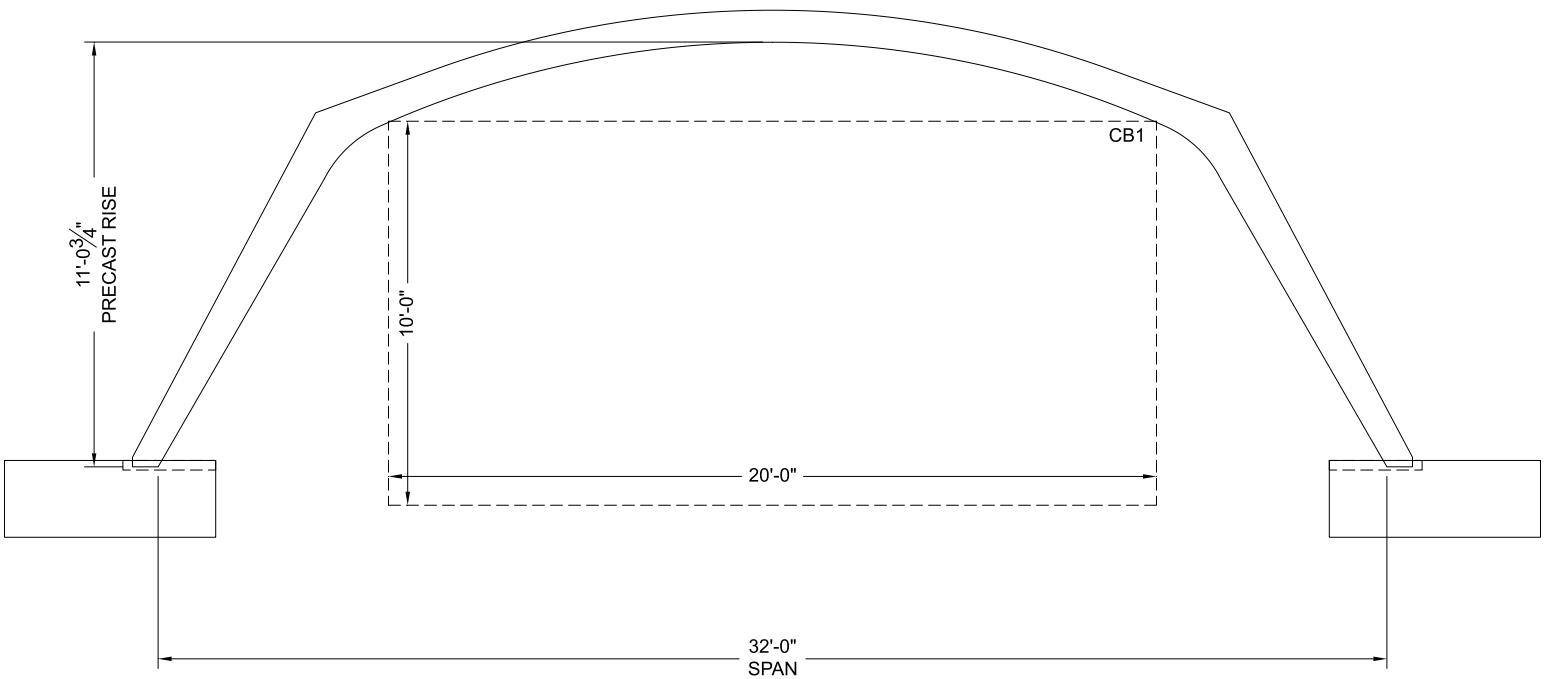
Price, UT

O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65294	DYO No.: 89508	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D2 OF D9		



LONGITUDINAL SECTION



CROSS SECTION

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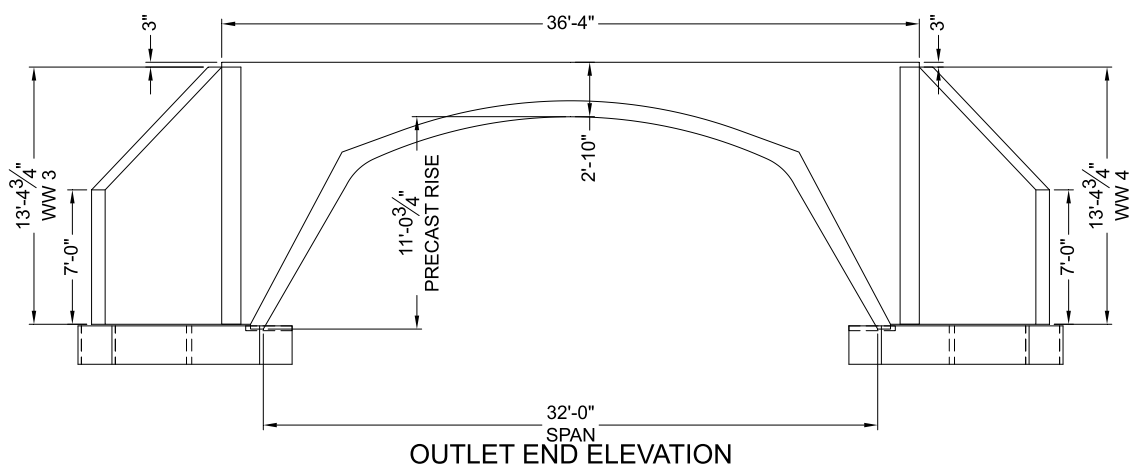
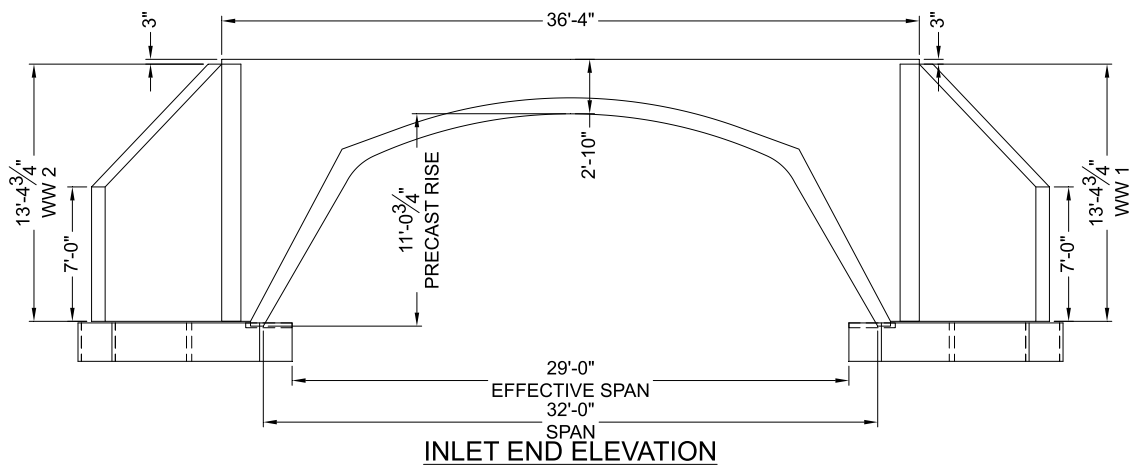
DYO89508, Wildlife Underpass MP 73.6

Conspan O

Price, UT

O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65294	DYO No.: 89508	DATE: 10/21/2025
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CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D3 OF D9		



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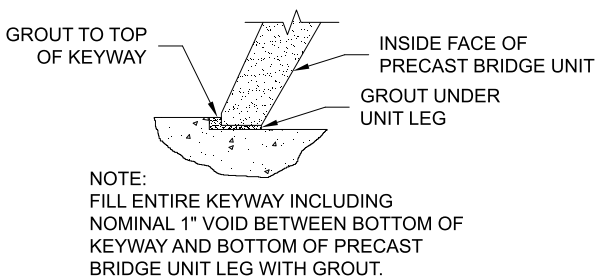
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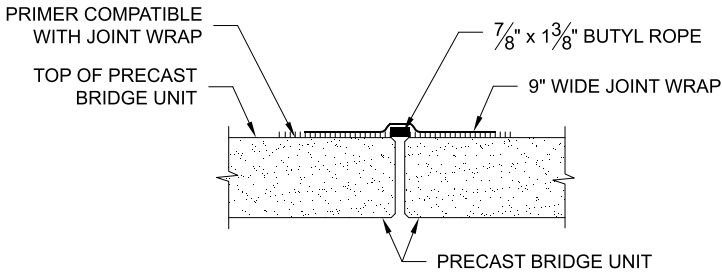
DYOB
DRAWING

DYO89508, Wildlife Underpass MP 73.6
Conspan O
Price, UT
O Series, 32' Span x 11'-0 3/4" Rise

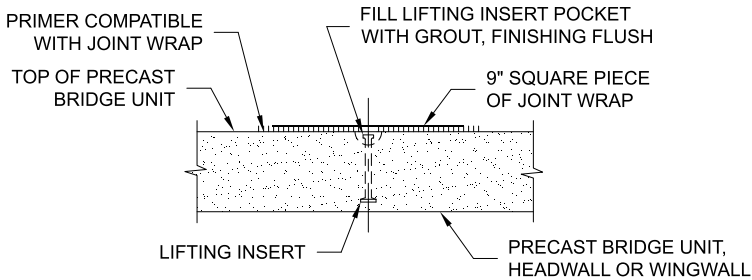
PROJECT No.: 65294	DYO No.: 89508	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D4 OF D9		



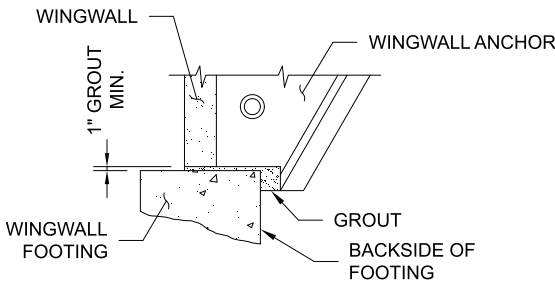
TYPICAL BRIDGE UNIT GROUT DETAIL
NOT TO SCALE



TYPICAL JOINT SEAL DETAIL
NOT TO SCALE

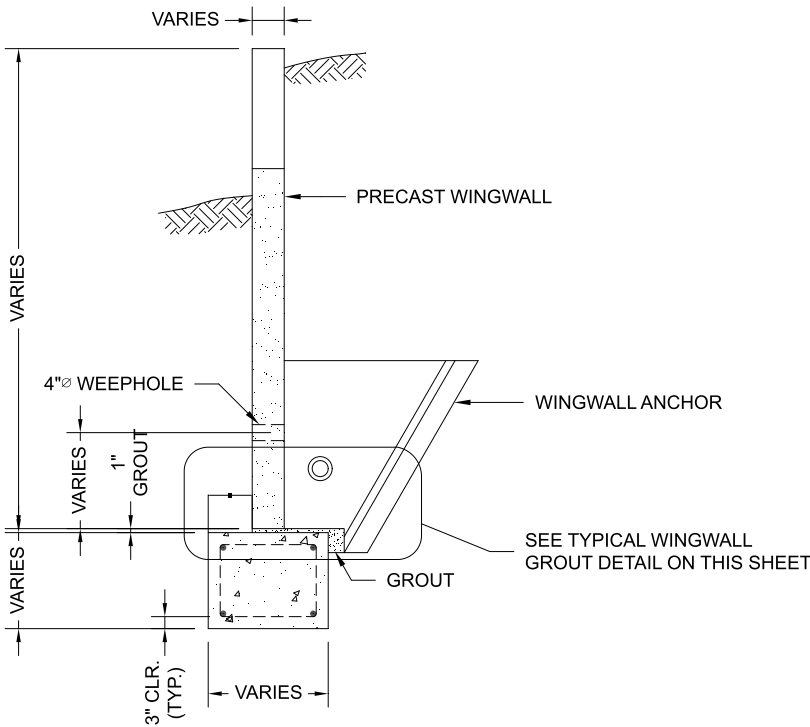


TYPICAL LIFT INSERT SEALING DETAIL
NOT TO SCALE



- NOTES:
- MINIMUM 1" GROUT UNDER WINGWALL LEG & ANCHOR STEM.
 - AREA BETWEEN WINGWALL FOOTING AND WINGWALL ANCHOR SHALL BE GROUTED SOLID BEFORE BACKFILL.
 - FORM BACKSIDE OF FOOTING TO DIMENSIONS SHOWN ON FOUNDATION PLAN.

TYPICAL WINGWALL GROUT DETAIL
NOT TO SCALE



TYPICAL WINGWALL SECTION
NOT TO SCALE

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CONSPAN
-SERIES

DYOB
DRAWING

DYO89508, Wildlife Underpass MP 73.6
Conspan O
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O Series, 32' Span x 11'-0 3/4" Rise

PROJECT No.: 65294	DYO No.: 89508	DATE: 10/21/2025
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D5 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS

- DESCRIPTION**
- 1.1. TYPE - THIS WORK SHALL CONSIST OF FURNISHING AND CONSTRUCTING A CON/SPAN® O-SERIES BRIDGE SYSTEM IN ACCORDANCE WITH THESE SPECIFICATIONS AND IN REASONABLY CLOSE CONFORMITY WITH THE LINES, GRADES, DESIGN AND DIMENSIONS SHOWN ON THE PLANS OR AS ESTABLISHED BY THE ENGINEER. IN SITUATIONS WHERE TWO OR MORE SPECIFICATIONS APPLY TO THIS WORK, THE MOST STRINGENT REQUIREMENTS SHALL GOVERN.
- 1.2. DESIGNATION - PRECAST REINFORCED CONCRETE CON/SPAN® O-SERIES BRIDGE UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY SPAN AND RISE. PRECAST REINFORCED CONCRETE WINGWALLS AND HEADWALLS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT, AND DEFLECTION ANGLE. PRECAST REINFORCED CONCRETE EXPRESS™ FOUNDATION UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT AND WIDTH.
- 2. DESIGN**
- 2.1. SPECIFICATIONS - THE PRECAST ELEMENTS ARE DESIGNED IN ACCORDANCE WITH THE "AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS" 8TH EDITION, ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2017. A MINIMUM OF ONE FOOT OF COVER ABOVE THE CROWN OF THE BRIDGE UNITS IS REQUIRED IN THE INSTALLED CONDITION. (UNLESS NOTED OTHERWISE ON THE SHOP DRAWINGS AND DESIGNED ACCORDINGLY.)
- 3. MATERIALS**
- 3.1. CONCRETE - THE CONCRETE FOR THE PRECAST ELEMENTS SHALL BE AIR-ENTRAINED WHEN INSTALLED IN AREAS SUBJECT TO FREEZE-THAW CONDITIONS, COMPOSED OF PORTLAND CEMENT, FINE AND COARSE AGGREGATES, ADMIXTURES AND WATER. AIR-ENTRAINED CONCRETE SHALL CONTAIN 6 ± 2 PERCENT AIR. THE AIR-ENTRAINING ADMIXTURE SHALL CONFORM TO AASHTO M154. THE MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE AS SHOWN ON THE SHOP DRAWINGS.
- 3.1.1. PORTLAND CEMENT - SHALL CONFORM TO THE REQUIREMENTS OF ASTM SPECIFICATIONS C150-TYPE I, TYPE II, OR TYPE III CEMENT.
- 3.1.2. COARSE AGGREGATE - SHALL CONSIST OF STONE HAVING A MAXIMUM SIZE OF 1 INCH. AGGREGATE SHALL MEET REQUIREMENTS FOR ASTM C33.
- 3.1.3. WATER REDUCING ADMIXTURE - THE MANUFACTURER MAY SUBMIT, FOR APPROVAL BY THE ENGINEER, A WATER-REDUCING ADMIXTURE FOR THE PURPOSE OF INCREASING WORKABILITY AND REDUCING THE WATER REQUIREMENT FOR THE CONCRETE.
- 3.1.4. CALCIUM CHLORIDE - THE ADDITION TO THE MIX OF CALCIUM CHLORIDE OR ADMIXTURES CONTAINING CALCIUM CHLORIDE WILL NOT BE PERMITTED.
- 3.1.5. MIXTURE - THE AGGREGATES, CEMENT AND WATER SHALL BE PROPORTIONED AND MIXED IN A BATCH MIXER TO PRODUCE A HOMOGENEOUS CONCRETE MEETING THE STRENGTH REQUIREMENTS OF THIS SPECIFICATION. THE PROPORTION OF PORTLAND CEMENT IN THE MIXTURE SHALL NOT BE LESS THAN 564 POUNDS (6 SACKS) PER CUBIC YARD OF CONCRETE.
- 3.2. STEEL REINFORCEMENT
- 3.2.1. THE MINIMUM STEEL YIELD STRENGTH SHALL BE 60,000 PSI, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS.
- 3.2.2. ALL REINFORCING STEEL FOR THE PRECAST ELEMENTS SHALL BE FABRICATED AND PLACED IN ACCORDANCE WITH THE DETAILED SHOP DRAWINGS SUBMITTED BY THE MANUFACTURER.
- 3.2.3. REINFORCEMENT SHALL CONSIST OF WELDED WIRE REINFORCING CONFORMING TO ASTM SPECIFICATION A 1064, OR DEFORMED STEEL BARS CONFORMING TO ASTM SPECIFICATION A 615, GRADE 60. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY CONSIST OF WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS.
- 3.3. STEEL HARDWARE
- 3.3.1. BOLTS AND THREADED RODS FOR WINGWALL CONNECTIONS SHALL CONFORM TO ASTM A 307. NUTS SHALL CONFORM TO AASHTO M292 (ASTM A194) GRADE 2H. ALL BOLTS, THREADED RODS AND NUTS USED IN WINGWALL CONNECTIONS SHALL BE MECHANICALLY ZINC COATED IN ACCORDANCE WITH ASTM B695 CLASS 50.
- 3.3.2. STRUCTURAL STEEL FOR WINGWALL CONNECTION PLATES AND PLATE WASHERS SHALL CONFORM TO AASHTO M 270 (ASTM A 709) GRADE 36 AND SHALL BE HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).
- 3.3.3. INSERTS FOR WINGWALLS SHALL BE 1" DIAMETER TWO-BOLT PRESET WINGWALL ANCHORS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED IN ACCORDANCE WITH ASTM B633 SC-1.
- 3.3.4. FERRULE LOOP INSERTS SHALL BE F-64 FERRULE LOOP INSERTS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED.
- 3.3.5. HOOK BOLTS USED IN ATTACHED HEADWALL CONNECTIONS SHALL BE ASTM A307.
- 3.3.6. INSERTS FOR DETACHED HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL, EXPANDED COIL INSERTS AS MANUFACTURED BY DAYTON SUPERIOR

CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700. COIL RODS AND NUTS USED IN HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL. WASHERS USED IN HEADWALL CONNECTIONS SHALL BE EITHER AISI TYPE 304 STAINLESS STEEL PLATE WASHERS OR AASHTO M270 (ASTM A709) GRADE 36 PLATE WASHERS HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123). MECHANICAL SPLICES OF REINFORCING BARS SHALL BE MADE USING THE DOWEL BAR SPLICER SYSTEM AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700, AND SHALL CONSIST OF THE DBDI SPLICE SYSTEM (DOWEL BAR SPLICER AND DOWEL-IN), OR AS MANUFACTURED BY BARSPLICE PRODUCTS INC, DAYTON, OHIO, (937)-275-8700, AND SHALL CONSIST OF BARSPLICER XP TYPE 2 SYSTEM.

- MANUFACTURE OF PRECAST ELEMENTS - SUBJECT TO THE PROVISIONS OF SECTION 5, BELOW, THE PRECAST ELEMENT DIMENSION AND REINFORCEMENT DETAILS SHALL BE AS PRESCRIBED IN THE PLAN AND SHOP DRAWINGS PROVIDED BY THE MANUFACTURER.**
- 4.1. FORMS - THE FORMS USED IN MANUFACTURE SHALL BE SUFFICIENTLY RIGID AND ACCURATE TO MAINTAIN THE REQUIRED PRECAST ELEMENT DIMENSIONS WITHIN THE PERMISSIBLE VARIATIONS GIVEN IN SECTION 5 OF THESE SPECIFICATIONS. ALL CASTING SURFACES SHALL BE OF A SMOOTH MATERIAL.**
- 4.2. PLACEMENT OF REINFORCEMENT**
- 4.2.1. PLACEMENT OF REINFORCEMENT IN PRECAST BRIDGE UNITS - THE COVER OF CONCRETE OVER THE OUTSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 2" MINIMUM. THE COVER OF CONCRETE OVER THE INSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 1½" MINIMUM, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS. THE CLEAR DISTANCE OF THE END CIRCUMFERENTIAL WIRES SHALL NOT BE LESS THAN 1" NOR MORE THAN 2" FROM THE ENDS OF EACH SECTION. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING SINGLE OR MULTIPLE LAYERS OF WELDED WIRE FABRIC (NOT TO EXCEED 3 LAYERS), SUPPLEMENTED WITH A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS, WHEN NECESSARY. WELDED WIRE FABRIC SHALL BE COMPOSED OF CIRCUMFERENTIAL AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE BRIDGE UNIT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW. THE ENDS OF THE LONGITUDINAL DISTRIBUTION REINFORCEMENT SHALL BE NOT MORE THAN 3" AND NOT LESS THAN 1½" FROM THE ENDS OF THE BRIDGE UNIT.**
- 4.2.2. BENDING OF REINFORCEMENT FOR PRECAST BRIDGE UNITS - THE OUTSIDE AND INSIDE CIRCUMFERENTIAL REINFORCING STEEL FOR THE CORNERS OF THE BRIDGE SHALL BE BENT TO SUCH AN ANGLE THAT IS APPROXIMATELY EQUAL TO THE CONFIGURATION OF THE BRIDGE'S OUTSIDE CORNER.**
- 4.2.3. PLACEMENT OF REINFORCEMENT FOR PRECAST WINGWALLS AND HEADWALLS - THE COVER OF CONCRETE OVER THE LONGITUDINAL AND TRANSVERSE REINFORCEMENT SHALL BE 2" MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 1½" NOR MORE THAN 3". REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC, OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.**
- 4.2.4. PLACEMENT OF REINFORCEMENT FOR PRECAST FOUNDATION UNITS - THE COVER OF CONCRETE OVER THE BOTTOM REINFORCEMENT SHALL BE 3 INCHES MINIMUM. THE COVER OF CONCRETE FOR ALL OTHER REINFORCEMENT SHALL BE 2 INCHES MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 2 INCHES NOR MORE THAN 3 INCHES. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.**
- 4.3. LAPS, WELDS, SPACING**
- 4.3.1. LAPS, WELDS, AND SPACING FOR PRECAST BRIDGE UNITS - TENSION SPLICES IN THE CIRCUMFERENTIAL REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS**

MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. THE OVERLAP OF WELDED WIRE FABRIC SHALL BE MEASURED BETWEEN THE OUTER-MOST LONGITUDINAL WIRES OF EACH FABRIC SHEET. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1 FOR SPLICES OTHER THAN TENSION SPLICES. THE OVERLAP SHALL BE A MINIMUM OF 1'-0" FOR WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS. THE SPACING CENTER TO CENTER OF THE CIRCUMFERENTIAL WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 4". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL WIRES SHALL NOT BE MORE THAN 8". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL DISTRIBUTION STEEL FOR EITHER LINE OF REINFORCING IN THE TOP SLAB SHALL BE NOT MORE THAN 1'-4". LAPS, WELDS, AND SPACING FOR PRECAST WINGWALLS, HEADWALLS AND FOUNDATIONS - SPLICES IN THE REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1. THE SPACING CENTER-TO-CENTER OF THE WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 8".

4. CURING - THE PRECAST CONCRETE ELEMENTS SHALL BE CURED FOR A SUFFICIENT LENGTH OF TIME SO THAT THE CONCRETE WILL DEVELOP THE SPECIFIED COMPRESSIVE STRENGTH IN 28 DAYS OR LESS. ANY ONE OF THE FOLLOWING METHODS OF CURING OR COMBINATIONS THERE OF SHALL BE USED:
- 4.4.1. STEAM CURING - THE PRECAST ELEMENTS MAY BE LOW-PRESSURE STEAM CURED BY A SYSTEM THAT WILL MAINTAIN A MOIST ATMOSPHERE.
- 4.4.2. WATER CURING - THE PRECAST ELEMENTS MAY BE WATER CURED BY ANY METHOD THAT WILL KEEP THE SECTIONS MOIST.
- 4.4.3. MEMBRANE CURING - A SEALING MEMBRANE CONFORMING TO THE REQUIREMENTS OF ASTM SPECIFICATION C309 MAY BE APPLIED AND SHALL BE LEFT INTACT UNTIL THE REQUIRED CONCRETE COMPRESSIVE STRENGTH IS ATTAINED. THE CONCRETE TEMPERATURE AT THE TIME OF APPLICATION SHALL BE WITHIN +/- 10 DEGREES F OF THE ATMOSPHERIC TEMPERATURE. ALL SURFACES SHALL BE KEPT MOIST PRIOR TO THE APPLICATION OF THE COMPOUNDS AND SHALL BE DAMP WHEN THE COMPOUND IS APPLIED.
- 4.5. STORAGE, HANDLING & DELIVERY
- 4.5.1. STORAGE - PRECAST CONCRETE BRIDGE ELEMENTS SHALL BE LIFTED AND STORED IN "AS-CAST" POSITION. PRECAST CONCRETE HEADWALL AND WINGWALL UNITS ARE CAST, STORED AND SHIPPED IN A FLAT POSITION. THE PRECAST ELEMENTS SHALL BE STORED IN SUCH A MANNER TO PREVENT CRACKING OR DAMAGE. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE. THE UNITS SHALL NOT BE MOVED UNTIL THE CONCRETE COMPRESSIVE STRENGTH HAS REACHED A MINIMUM OF 2500 PSI (3000 PSI FOR SPANS >48 FEET), AND THEY SHALL NOT BE STORED IN AN UPRIGHT POSITION.
- 4.5.2. HANDLING - HANDLING DEVICES SHALL BE PERMITTED IN EACH PRECAST ELEMENT FOR THE PURPOSE OF HANDLING AND SETTING. SPREADER BEAMS MAY BE REQUIRED FOR THE LIFTING OF PRECAST CONCRETE BRIDGE ELEMENTS TO PRECLUDE DAMAGE FROM BENDING OR TORSION FORCES.
- 4.5.3. DELIVERY - PRECAST CONCRETE ELEMENTS MUST NOT BE SHIPPED UNTIL THE CONCRETE HAS ATTAINED THE SPECIFIED DESIGN COMPRESSIVE STRENGTH, OR AS DIRECTED BY THE DESIGN ENGINEER. PRECAST CONCRETE ELEMENTS MAY BE UNLOADED AND PLACED ON THE GROUND AT THE SITE UNTIL INSTALLED. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE.
- 4.6. QUALITY ASSURANCE - THE PRECASTER SHALL DEMONSTRATE ADHERENCE TO THE STANDARDS SET FORTH IN THE NPCA QUALITY CONTROL MANUAL. THE PRECASTER SHALL MEET EITHER SECTION 4.6.1 OR 4.6.2
- 4.6.1. CERTIFICATION - THE PRECASTER SHALL BE CERTIFIED BY THE PRECAST/PRESTRESSED CONCRETE INSTITUTE PLANT CERTIFICATION PROGRAM OR THE NATIONAL PRECAST CONCRETE ASSOCIATION'S PLANT CERTIFICATION PROGRAM PRIOR TO AND DURING PRODUCTION OF THE PRODUCTS COVERED BY THIS SPECIFICATION.
- 4.6.2. QUALIFICATIONS, TESTING AND INSPECTION
- 4.6.2.1. THE PRECASTER SHALL HAVE BEEN IN THE BUSINESS OF PRODUCING PRECAST CONCRETE PRODUCTS SIMILAR TO THOSE SPECIFIED FOR A MINIMUM OF THREE YEARS. HE SHALL MAINTAIN A PERMANENT QUALITY CONTROL DEPARTMENT OR RETAIN AN INDEPENDENT TESTING AGENCY ON A CONTINUING BASIS. THE AGENCY SHALL ISSUE A REPORT, CERTIFIED BY A LICENSED ENGINEER, DETAILING THE ABILITY OF THE PRECASTER TO PRODUCE QUALITY PRODUCTS CONSISTENT WITH INDUSTRY STANDARDS.
- 4.6.2.2. THE PRECASTER SHALL SHOW THAT THE

FOLLOWING TESTS ARE PERFORMED IN
 ACCORDANCE WITH THE ASTM STANDARDS
 INDICATED. TESTS SHALL BE PERFORMED AS
 INDICATED IN SECTION 6 OF THESE
 SPECIFICATIONS.

- 4.6.2.2.1. AIR CONTENT: C231 OR C173
4.6.2.2.2. COMPRESSIVE STRENGTH: C31,C39,C497
4.6.2.3. THE PRECASTER SHALL PROVIDE DOCUMENTATION DEMONSTRATING COMPLIANCE WITH THIS SECTION TO CONTECH® ENGINEERED SOLUTIONS AT REGULAR INTERVALS OR UPON REQUEST.
4.6.2.4. THE OWNER MAY PLACE AN INSPECTOR IN THE PLANT WHEN THE PRODUCTS COVERED BY THIS SPECIFICATION ARE BEING MANUFACTURED.
4.6.3.DOCUMENTATION - THE PRECASTER SHALL SUBMIT PRECAST PRODUCTION REPORTS TO CONTECH® ENGINEERED SOLUTIONS AS REQUIRED.
5. PERMISSIBLE VARIATIONS
5.1. BRIDGE UNITS
5.1.1.INTERNAL DIMENSIONS - THE INTERNAL DIMENSION SHALL VARY NOT MORE THAN 1% FROM THE DESIGN DIMENSIONS NOR MORE THAN 1½" WHICHEVER IS LESS.
5.1.2. SLAB AND WALL THICKNESS - THE SLAB AND WALL THICKNESS SHALL NOT BE LESS THAN THAT SHOWN IN THE DESIGN BY MORE THAN ½". A THICKNESS MORE THAN THAT REQUIRED IN THE DESIGN SHALL NOT BE CAUSE FOR REJECTION.
5.1.3. LENGTH OF OPPOSITE SURFACES - VARIATIONS IN LAYING LENGTHS OF TWO OPPOSITE SURFACES OF THE BRIDGE UNIT SHALL NOT BE MORE THAN ½" IN ANY SECTION, EXCEPT WHERE BEVELED ENDS FOR LAYING OF CURVES ARE SPECIFIED BY THE PURCHASER.
5.1.4. LENGTH OF SECTION - THE UNDERRUN IN LENGTH OF A SECTION SHALL NOT BE MORE THAN ½" IN ANY BRIDGE UNIT.
5.1.5. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½" FOR THE OUTSIDE CIRCUMFERENTIAL STEEL OR BE LESS THAN 1" FOR THE INSIDE CIRCUMFERENTIAL STEEL AS MEASURED TO THE EXTERNAL OR INTERNAL SURFACE OF THE BRIDGE. THESE TOLERANCES OR COVER REQUIREMENTS DO NOT APPLY TO MATING SURFACES OF THE JOINTS.
5.1.6. AREA OF REINFORCEMENT - THE AREAS OF STEEL REINFORCEMENT SHALL BE THE DESIGN STEEL AREAS AS SHOWN IN THE MANUFACTURER'S SHOP DRAWINGS. STEEL AREAS GREATER THAN THOSE REQUIRED SHALL NOT BE CAUSE FOR REJECTION. THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCEMENT SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCEMENT.
- 5.2. WINGWALLS & HEADWALLS
5.2.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.2.2. LENGTH/HEIGHT OF WALL SECTIONS - THE LENGTH AND HEIGHT OF THE WALL SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.2.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
5.2.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.
- 5.3. FOUNDATION UNITS
5.3.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.3.2. LENGTH/ HEIGHT/WIDTH OF FOUNDATION SECTIONS - THE LENGTH, HEIGHT AND WIDTH OF THE FOUNDATION UNITS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
5.3.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ± ½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
5.3.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.
6. TESTING/ INSPECTION
6.1. TESTING
6.1.1. TYPE OF TEST SPECIMEN - CONCRETE COMPRESSIVE STRENGTH SHALL BE DETERMINED FROM COMPRESSION TESTS MADE ON CYLINDERS OR CORES. FOR CYLINDER TESTING, A MINIMUM OF 4 CYLINDERS SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. FOR CORE TESTING, A MINIMUM OF 2 CORES SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. EACH ELEMENT SHALL BE CONSIDERED SEPARATELY FOR THE PURPOSE OF TESTING AND ACCEPTANCE.
6.1.2. COMPRESSION TESTING - CYLINDERS SHALL BE MADE AND TESTED AS PRESCRIBED BY THE ASTM C39 SPECIFICATION. CYLINDERS SHALL BE CURED IN THE SAME ENVIRONMENT AS THE BRIDGE ELEMENTS. CORES SHALL BE OBTAINED AND TESTED FOR COMPRESSIVE STRENGTH FROM EACH ELEMENT IN ACCORDANCE WITH THE PROVISIONS OF THE

ASTM C42 SPECIFICATION. ACCEPTABILITY OF CYLINDER TESTS - WHEN THE AVERAGE COMPRESSIVE STRENGTH OF ALL CYLINDERS TESTED IS EQUAL TO OR GREATER THAN THE DESIGN COMPRESSIVE STRENGTH, AND NOT MORE THAN 10% OF THE CYLINDERS TESTED HAVE A COMPRESSIVE STRENGTH LESS THAN THE DESIGN CONCRETE STRENGTH, AND NO CYLINDER TESTED HAS A COMPRESSIVE STRENGTH LESS THAN 90% OF THE REQUIRED CONCRETE STRENGTH, THEN THE ELEMENT SHALL BE ACCEPTED. WHEN THE COMPRESSIVE STRENGTH OF THE CYLINDERS TESTED DOES NOT CONFORM TO THESE ACCEPTANCE CRITERIA, THE ACCEPTABILITY OF THE ELEMENT MAY BE DETERMINED AS DESCRIBED IN SECTION 6.1.4. BELOW.

- 6.1.4. ACCEPTABILITY OF CORE TESTS - THE COMPRESSIVE STRENGTH OF THE CONCRETE IN A BRIDGE ELEMENT IS ACCEPTABLE WHEN EACH CORE TEST STRENGTH IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH. WHEN THE COMPRESSIVE STRENGTH OF A CORE TESTED IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN MAY BE RE-CORED. WHEN THE COMPRESSIVE STRENGTH OF THE RE-CORE IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH, THE COMPRESSIVE STRENGTH OF THE CONCRETE IN THAT BRIDGE ELEMENT IS ACCEPTABLE.
- 6.1.4.1. WHEN THE COMPRESSIVE STRENGTH OF ANY RECORE IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN SHALL BE REJECTED.
- 6.1.4.2. PLUGGING CORE HOLES - THE CORE HOLES SHALL BE PLUGGED AND SEALED BY THE MANUFACTURER IN A MANNER SUCH THAT THE ELEMENTS WILL MEET ALL OF THE TEST REQUIREMENTS OF THIS SPECIFICATION. PRECAST ELEMENTS SO SEALED SHALL BE CONSIDERED SATISFACTORY FOR USE.
- 6.1.4.3. TEST EQUIPMENT - EVERY MANUFACTURER FURNISHING PRECAST ELEMENTS UNDER THIS SPECIFICATION SHALL FURNISH ALL FACILITIES AND PERSONNEL NECESSARY TO CARRY OUT THE TEST REQUIRED.
- INSPECTION - THE QUALITY OF MATERIALS, THE PROCESS OF MANUFACTURE, AND THE FINISHED PRECAST ELEMENTS SHALL BE SUBJECT TO INSPECTION BY THE PURCHASER.

7. JOINTS
THE BRIDGE UNITS SHALL BE PRODUCED WITH FLAT BUTT ENDS. THE ENDS OF THE BRIDGE UNITS SHALL BE SUCH THAT WHEN THE SECTIONS ARE LAID TOGETHER THEY WILL MAKE A CONTINUOUS LINE WITH A SMOOTH INTERIOR FREE OF APPRECIABLE IRREGULARITIES, ALL COMPATIBLE WITH THE PERMISSIBLE VARIATIONS IN SECTION 5, ABOVE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED ¾".
8. WORKMANSHIP/ FINISH
THE BRIDGE UNITS, WINGWALLS, HEADWALLS AND FOUNDATION UNITS SHALL BE SUBSTANTIALLY FREE OF FRACTURES. THE ENDS OF THE BRIDGE UNITS SHALL BE NORMAL TO THE WALLS AND CENTERLINE OF THE BRIDGE SECTION, WITHIN THE LIMITS OF THE VARIATIONS GIVEN IN SECTION 5, ABOVE, EXCEPT WHERE BEVELED ENDS ARE SPECIFIED. THE FACES OF THE WINGWALLS AND HEADWALLS SHALL BE PARALLEL TO EACH OTHER, WITHIN THE LIMITS OF VARIATIONS GIVEN IN SECTION 5, ABOVE. THE SURFACE OF THE PRECAST ELEMENTS SHALL BE A SMOOTH STEEL FORM OR TROWELED SURFACE. TRAPPED AIR POCKETS CAUSING SURFACE DEFECTS SHALL BE CONSIDERED AS PART OF A SMOOTH, STEEL FORM FINISH.
9. REPAIRS
PRECAST ELEMENTS MAY BE REPAIRED, IF NECESSARY, BECAUSE OF IMPERFECTIONS IN MANUFACTURE OR HANDLING DAMAGE AND WILL BE ACCEPTABLE IF, IN THE OPINION OF THE PURCHASER, THE REPAIRS ARE SOUND, PROPERLY FINISHED AND CURED, AND THE REPAIRED SECTION CONFORMS TO THE REQUIREMENTS OF THIS SPECIFICATION.
10. REJECTION
THE PRECAST ELEMENTS SHALL BE SUBJECT TO REJECTION ON ACCOUNT OF ANY OF THE SPECIFICATION REQUIREMENTS. INDIVIDUAL PRECAST ELEMENTS MAY BE REJECTED BECAUSE OF ANY OF THE FOLLOWING:
- 10.1. FRACTURES OR CRACKS PASSING THROUGH THE WALL, EXCEPT FOR A SINGLE END CRACK THAT DOES NOT EXCEED ONE HALF THE THICKNESS OF THE WALL.
- 10.2. DEFECTS THAT INDICATE PROPORTIONING, MIXING, AND MOLDING NOT IN COMPLIANCE WITH SECTION 4 OF THESE SPECIFICATIONS.
- 10.3. HONEYCOMBED OR OPEN TEXTURE.
- 10.4. DAMAGED ENDS, WHERE SUCH DAMAGE WOULD PREVENT MAKING A SATISFACTORY JOINT.

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DYOB DRAWING

CON/SPAN O-SERIES SPECIFICATIONS

PROJECT NO.:	SEQ. NO.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.: D6 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS (CONT'D)

11. **MARKING**
EACH BRIDGE UNIT SHALL BE CLEARLY MARKED BY WATERPROOF PAINT. THE FOLLOWING SHALL BE SHOWN ON THE INSIDE OF THE VERTICAL LEG OF THE BRIDGE SECTION:
BRIDGE SPAN X BRIDGE RISE
DATE OF MANUFACTURE
NAME OR TRADEMARK OF THE MANUFACTURER

12. **INSTALLATION PREPARATION**
TO ENSURE CORRECT INSTALLATION OF THE PRECAST CONCRETE BRIDGE SYSTEM, CARE AND CAUTION MUST BE EXERCISED IN FORMING THE SUPPORT AREAS FOR BRIDGE UNITS, HEADWALL, AND WINGWALL ELEMENTS. EXERCISING SPECIAL CARE WILL FACILITATE THE RAPID INSTALLATION OF THE PRECAST COMPONENTS.

- 12.1. **FOOTINGS**
DO NOT OVER EXCAVATE FOUNDATIONS UNLESS DIRECTED BY SITE SOIL ENGINEER TO REMOVE UNSUITABLE SOIL.

THE SITE SOILS ENGINEER SHALL CERTIFY THAT THE BEARING CAPACITY MEETS OR EXCEEDS THE FOOTING DESIGN REQUIREMENTS, PRIOR TO THE CONTRACTOR POURING OF THE FOOTINGS.

THE BRIDGE UNITS AND WINGWALLS SHALL BE INSTALLED ON EITHER PRECAST OR CAST-IN-PLACE CONCRETE FOOTINGS. THE SIZE AND ELEVATION OF THE FOOTINGS SHALL BE AS DESIGNED BY THE ENGINEER. A KEYWAY SHALL BE FORMED IN THE TOP SURFACE OF THE BRIDGE FOOTING AS SPECIFIED ON THE PLANS. NO KEYWAY IS REQUIRED IN THE WINGWALL FOOTINGS, UNLESS OTHERWISE SPECIFIED ON THE PLANS.

THE FOOTINGS SHALL BE GIVEN A SMOOTH FLOAT FINISH AND SHALL REACH A COMPRESSIVE STRENGTH OF 2,000 PSI BEFORE PLACEMENT OF THE BRIDGE AND WINGWALL ELEMENTS. BACKFILLING SHALL NOT BEGIN UNTIL THE FOOTING HAS REACHED THE FULL DESIGN COMPRESSIVE STRENGTH.

THE FOOTING SURFACE SHALL BE CONSTRUCTED IN ACCORDANCE WITH GRADES SHOWN ON THE PLANS. WHEN TESTED WITH A 10'-0" STRAIGHT EDGE, THE SURFACE SHALL NOT VARY MORE THAN 1/4" IN 10'-0".

IF A PRECAST CONCRETE FOOTING IS USED, THE CONTRACTOR SHALL PREPARE A 4" THICK BASE LAYER OF COMPACTED GRANULAR MATERIAL THE FULL WIDTH OF THE FOOTING PRIOR TO PLACING THE PRECAST FOOTING.

THE FOUNDATIONS FOR PRECAST CONCRETE BRIDGE ELEMENTS AND WINGWALLS MUST BE CONNECTED BY REINFORCEMENT TO FORM ONE MONOLITHIC BODY. EXPANSION JOINTS SHALL NOT BE USED.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE CONSTRUCTION OF THE FOUNDATIONS PER THE PLANS AND SPECIFICATIONS.

13. **INSTALLATION**
13.1. **GENERAL** - THE INSTALLATION OF THE PRECAST CONCRETE ELEMENTS SHALL BE AS EXPLAINED IN THE PUBLICATION CON/SPAN BRIDGE SYSTEMS INSTALLATION HANDBOOK.

- 13.1.1. **LIFTING** - IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO ENSURE THAT A CRANE OF THE CORRECT LIFTING CAPACITY IS AVAILABLE TO HANDLE THE PRECAST CONCRETE UNITS. THIS CAN BE ACCOMPLISHED BY USING THE WEIGHTS GIVEN FOR THE PRECAST CONCRETE COMPONENTS AND BY DETERMINING THE LIFTING REACH FOR EACH CRANE UNIT. SITE CONDITIONS MUST BE CHECKED WELL IN ADVANCE OF SHIPPING TO ENSURE PROPER CRANE LOCATION AND TO AVOID ANY LIFTING RESTRICTIONS. THE LIFT ANCHORS OR HOLES PROVIDED IN EACH UNIT ARE THE ONLY MEANS TO BE USED TO LIFT THE ELEMENTS. THE PRECAST CONCRETE ELEMENTS MUST NOT BE SUPPORTED OR RAISED BY OTHER MEANS THAN THOSE GIVEN IN THE MANUALS AND DRAWINGS WITHOUT WRITTEN APPROVAL FROM CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2. **CONSTRUCTION EQUIPMENT WEIGHT RESTRICTIONS** - IN NO CASE SHALL EQUIPMENT OPERATING IN EXCESS OF THE DESIGN LOAD (HL-93) BE PERMITTED OVER THE BRIDGE UNITS UNLESS APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

- 13.1.2.1. IN THE IMMEDIATE AREA OF THE BRIDGE UNITS, THE FOLLOWING RESTRICTIONS FOR THE USE OF HEAVY CONSTRUCTION MACHINERY DURING BACKFILLING OPERATIONS APPLY:

- NO CONSTRUCTION EQUIPMENT SHALL CROSS THE BARE PRECAST CONCRETE BRIDGE UNIT.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 4" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 10 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 1'-0" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 30 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED THE DESIGN COVER, OR 2'-0" MINIMUM, OVER THE CROWN OF THE PRECAST CONCRETE BRIDGE, CONSTRUCTION EQUIPMENT WITHIN THE DESIGN LOAD LIMITS FOR THE ROAD MAY CROSS THE PRECAST CONCRETE BRIDGE.

- 13.2. **LEVELING PAD/SHIMS** - THE BRIDGE UNITS AND WINGWALLS SHALL BE SET ON HARDBOARD SHIMS CONFORMING TO ASTM D1037 OR PLASTIC SHIMS (DAYTON SUPERIOR P-80, P-81 OR APPROVED EQUAL) MEASURING 5" x 5", MINIMUM, UNLESS SHOWN OTHERWISE ON THE PLANS. A MINIMUM GAP OF 1/2" SHALL BE PROVIDED BETWEEN THE FOOTING AND THE BOTTOM OF THE BRIDGE'S

VERTICAL LEGS OR THE BOTTOM OF THE WINGWALL. ALSO, A SUPPLY OF 1/4", 1/2" AND 3/8" THICK HARDBOARD OR PLASTIC SHIMS FOR VARIOUS SHIMMING PURPOSES SHALL BE ON SITE.

- 13.3. **PLACEMENT OF BRIDGE UNITS** - THE BRIDGE UNITS SHALL BE PLACED AS SHOWN ON THE ENGINEER'S PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED 1/4".

- 13.4. IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN THE STRUCTURE SPAN DURING ALL PHASES OF INSTALLATION. DUE TO THE ARCH SHAPE, BRIDGE ELEMENTS WILL TEND TO SPREAD UNDER SELF-WEIGHT. IT IS IMPERATIVE THAT ANY LATERAL SPREADING OF THE BRIDGE ELEMENTS BE AVOIDED DURING AND AFTER THEIR PLACEMENT. GENERALLY, HORIZONTAL CABLE TIES OR TIE RODS ARE SHIPPED IN THE LARGER BRIDGE ELEMENTS TO ASSIST IN PREVENTING THIS SPREADING. CABLE TIES/TIE RODS SHALL NOT BE REMOVED UNTILL BRIDGE UNITS ARE GROUTED AND GROUT HAS CURED. IT IS RECOMMENDED THAT TEMPORARY HARDWOOD BLOCKS BE USED IN CONJUNCTION WITH THE CABLE TIES/TIE RODS TO MAINTAIN SPAN. IF, HOWEVER, DUE TO SITE RESTRICTIONS, THESE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO PLACEMENT OF THE BRIDGE ELEMANTS, THE CONTRACTOR MUST NOTIFY CONTECH (MANUFACTURER) AND REQUEST A SUGGESTED INSTALLATION PROCEDURE.

IN ADDITION, IF THE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO SETTING ARCH UNITS, THE FOLLOWING QUALITY CONTROL PROCEDURE MUST BE FOLLOWED:

- 1) FIND "MEASURED SPAN" UPON ARCH UNIT'S DELIVERY TO SITE, PRIOR TO LIFTING FROM TRUCK AND REMOVING CABLE TIES/TIE RODS. "MEASURED SPAN" SHALL BE THE AVERAGE OF (3) SPAN MEASUREMENTS ALONG THE LAY LENGTH OF THE ARCH UNIT.
- 2) AFTER SETTING OF BRIDGE UNIT ON THE FOUNDATION, VERIFY THE SPAN. THIS "INSTALLED SPAN MEASUREMENT" SHALL NOT EXCEED THE MAXIMUM OF:
A) THE NOMINAL SPAN + 1/4" OR
B) THE "MEASURED SPAN"

IF THE "INSTALLED SPAN MEASUREMENT" EXCEEDS THIS AMOUNT, THE ARCH UNIT SHALL BE LIFTED AND RE-SET UNTIL THE "INSTALLED SPAN MEASUREMENT" MEETS THE LIMITS.

- 13.5. **PLACEMENT OF WINGWALLS, HEADWALLS AND FOUNDATION UNITS** - THE WINGWALLS, HEADWALLS AND FOUNDATIONS SHALL BE PLACED AS SHOWN ON THE PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE.

- 13.6. **JOINT PROTECTION AND SUBSURFACE DRAINAGE**

- 13.6.1. **EXTERNAL PROTECTION OF JOINTS** - THE BUTT JOINT MADE BY TWO ADJOINING BRIDGE UNITS SHALL BE COVERED WITH A 7/8" x 1 1/2" PREFORMED BITUMINOUS JOINT SEALANT AND A MINIMUM OF A 9" WIDE JOINT WRAP. THE SURFACE SHALL BE FREE OF DIRT BEFORE APPLYING THE JOINT MATERIAL. A PRIMER COMPATIBLE WITH THE JOINT WRAP TO BE USED SHALL BE APPLIED FOR A MINIMUM WIDTH OF 9" ON EACH SIDE OF THE JOINT. THE EXTERNAL WRAP SHALL BE CS212 BY CONCRETE SEALANTS INC., EZ-WRAP RUBBER BY PRESS-SEAL GASKET CORPORATION, SEAL WRAP BY MAR MAC MANUFACTURING CO. INC. OR APPROVED EQUAL. THE JOINT SHALL BE COVERED CONTINUOUSLY FROM THE BOTTOM OF ONE BRIDGE SECTION LEG, ACROSS THE TOP OF THE BRIDGE AND TO THE OPPOSITE BRIDGE SECTION LEG. ANY LAPS THAT RESULT IN THE JOINT WRAP SHALL BE A MINIMUM OF 6" LONG WITH THE OVERLAP RUNNING DOWNHILL.

- 13.6.2. **IN ADDITION TO THE JOINTS BETWEEN BRIDGE UNITS, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE HEADWALL SHALL ALSO BE SEALED AS DESCRIBED ABOVE. IF PRECAST WINGWALLS ARE USED, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE WINGWALL SHALL BE SEALED WITH A 2'-0" STRIP OF FILTER FABRIC. ALSO, IF LIFT HOLES ARE FORMED IN THE BRIDGE UNITS, THEY SHALL BE PRIMED AND COVERED WITH A 9" x 9" SQUARE OF JOINT WRAP.**

- 13.6.3. **DURING THE BACKFILLING OPERATION, CARE SHALL BE TAKEN TO KEEP THE JOINT WRAP IN ITS PROPER LOCATION OVER THE JOINT.**

- 13.6.4. **SUBSOIL DRAINAGE SHALL BE AS DIRECTED BY THE ENGINEER.**

- 13.7. **GROUTING**

- 13.7.1. **GROUTING SHALL NOT BE PERFORMED WHEN TEMPERATURES ARE EXPECTED TO GO BELOW 35° FOR A PERIOD OF 72 HOURS. GROUTING SHOULD BE COMPLETED AS SOON AS PRACTICAL AFTER PRECAST ARCHES HAVE BEEN INSTALLED. FILL THE BRIDGE-FOUNDATION KEYWAY WITH CEMENT GROUT (PORTLAND CEMENT AND WATER OR CEMENT MORTAR COMPOSED OF PORTLAND CEMENT, SAND AND WATER) WITH A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 3000 PSI. VIBRATE AS REQUIRED TO ENSURE THAT THE ENTIRE KEY AROUND THE BRIDGE ELEMENT IS COMPLETELY FILLED. IF BRIDGE ELEMENTS HAVE BEEN SET WITH TEMPORARY TIES (CABLES, BARS, ETC.) GROUT MUST ATTAIN A MINIMUM COMPRESSIVE STRENGTH OF 1500 PSI BEFORE TIES MAY BE REMOVED.**

- 13.7.2. **ALL GROUT SHALL HAVE A MAXIMUM AGGREGATE SIZE OF 1/4".**

- 13.7.3. **LIFTING AND ERECTION ANCHOR RECESSES SHALL BE FILLED WITH GROUT.**

- 13.7.4. **AFTER GROUT HAS REACHED ITS DESIGN STRENGTH THE TEMPORARY HARDWOOD WEDGES SHALL BE REMOVED AND THEIR HOLES FILLED WITH GROUT.**

- 13.8. **BACKFILL**

- 13.8.1. **DO NOT PERFORM BACKFILLING DURING WET OR FREEZING**

WEATHER.
13.8.2. **NO BACKFILL SHALL BE PLACED AGAINST ANY STRUCTURAL ELEMENTS UNTIL THEY HAVE BEEN APPROVED BY THE ENGINEER.**

- 13.8.3. **BACKFILL SHALL BE CONSIDERED AS ALL REPLACED EXCAVATION AND NEW EMBANKMENT ADJACENT TO THE PRECAST CONCRETE ELEMENTS. THE PROJECT CONSTRUCTION AND MATERIAL SPECIFICATIONS, WHICH INCLUDE THE SPECIFICATIONS FOR EXCAVATION FOR STRUCTURES AND ROADWAY EXCAVATION AND EMBANKMENT CONSTRUCTION, SHALL APPLY EXCEPT AS MODIFIED IN THIS SECTION.**

- 13.8.4. **BACKFILL ZONES:**

- IN-SITU SOIL
- ZONE A: CONSTRUCTED EMBANKMENT OR OVERFILL.
- ZONE B: FILL THAT IS DIRECTLY ASSOCIATED WITH PRECAST CONCRETE BRIDGE INSTALLATION.
- ZONE C: ROAD STRUCTURE.

- 13.8.5. **REQUIRED BACKFILL PROPERTIES**

- 13.8.5.1. **IN-SITU SOIL** - NATURAL GROUND IS TO BE SUFFICIENTLY STABLE TO ALLOW EFFECTIVE SUPPORT TO THE PRECAST CONCRETE BRIDGE UNITS. AS A GUIDE, THE EXISTING NATURAL GROUND SHOULD BE OF SIMILAR QUALITY AND DENSITY TO ZONE B MATERIAL FOR MINIMUM LATERAL DIMENSION OF ONE BRIDGE SPAN OUTSIDE OF THE BRIDGE FOOTING.

- 13.8.5.2. **ZONE A - ZONE A REQUIRES FILL MATERIAL WITH SPECIFICATIONS AND COMPACTING PROCEDURES EQUAL TO THAT FOR NORMAL ROAD EMBANKMENTS.**

- 13.8.5.3. **ZONE B - GENERALLY, SOILS SHALL BE REASONABLY FREE OF ORGANIC MATTER, AND, NEAR CONCRETE SURFACES, FREE OF STONES LARGER THAN 3" IN DIAMETER SEE CHARTS FOR DETAILED DESCRIPTIONS OF ACCEPTABLE SOILS.**

- 13.8.5.4. **ZONE C - ZONE C IS THE ROAD SECTION OF GRAVEL, ASPHALT OR CONCRETE BUILT IN COMPLIANCE WITH LOCAL ENGINEERING PRACTICES.**

- 13.8.5.5. **GEOTECHNICAL ENGINEER SHALL REVIEW GRADATIONS OF ALL INTERFACING MATERIALS AND, IF NECESSARY, RECOMMEND GEOTEXTILE FILTER FABRIC (PROVIDED BY CONTRACTOR)**

- 13.8.6. **PLACING AND COMPACTING BACKFILL**
DUMPING FOR BACKFILLING IS NOT ALLOWED ANY NEARER THAN 3'-0" FROM THE BRIDGE LEG.

THE FILL MUST BE PLACED AND COMPACTED IN LAYERS NOT EXCEEDING 8". THE MAXIMUM DIFFERENCE IN THE SURFACE LEVELS OF THE FILL ON OPPOSITE SIDES OF THE BRIDGE MUST NOT EXCEED 2'-0".

THE FILL BEHIND WINGWALLS MUST BE PLACED AT THE SAME TIME AS THAT OF THE BRIDGE FILL. IT MUST BE PLACED IN PROGRESSIVELY PLACED HORIZONTAL LAYERS NOT EXCEEDING 8" PER LAYER.

THE BACKFILL OF ZONE B SHALL BE COMPACTED TO A MINIMUM DENSITY OF 95% OF THE STANDARD PROCTOR, AS REQUIRED BY AASHTO T-99.

SOIL WITHIN 1'-0" OF CONCRETE SURFACES SHALL BE HAND-COMPACTED. ELSEWHERE, USE OF ROLLERS IS ACCEPTABLE. IF VIBRATING ROLLER-COMPACTORS ARE USED, THEY SHALL NOT BE STARTED OR STOPPED WITHIN ZONE B AND THE VIBRATION FREQUENCY SHOULD BE AT LEAST 30 REVOLUTIONS PER SECOND.

THE BACKFILL MATERIAL AND COMPACTING BEHIND WINGWALLS SHALL SATISFY THE CRITERIA FOR THE BRIDGE BACKFILL, ZONE B.

BACKFILL AGAINST A WATERPROOFED SURFACE SHALL BE PLACED CAREFULLY TO AVOID DAMAGE TO THE WATERPROOFING MATERIAL.

- 13.8.7. **BRIDGE UNITS**
FOR FILL HEIGHTS OVER 12 FEET (AS MEASURED FROM TOP CROWN OF BRIDGE TO FINISHED GRADE), NO BACKFILLING MAY BEGIN UNTIL A BACKFILL COMPACTION TESTING PLAN HAS BEEN COORDINATED WITH AND APPROVED BY CONTECH® ENGINEERED SOLUTIONS.

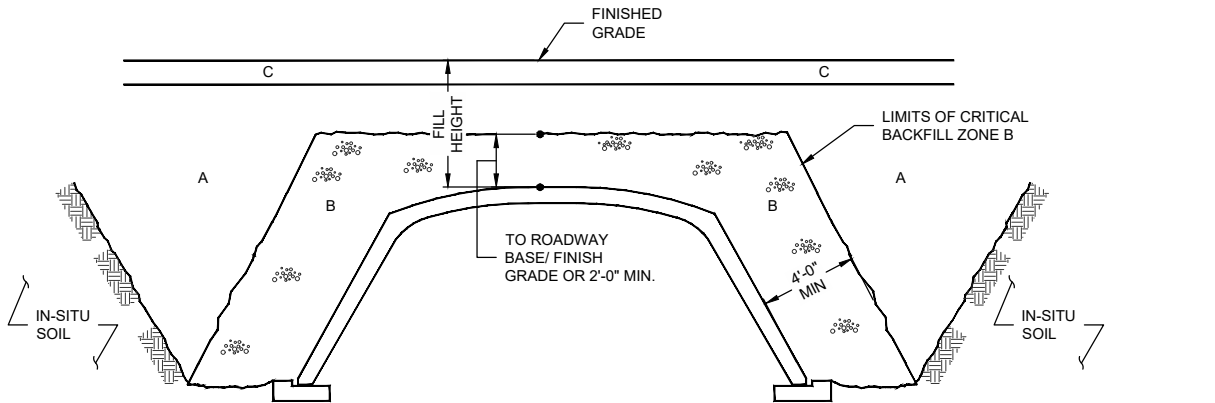
- 13.8.8. **WINGWALLS**
BACKFILL IN FRONT OF WINGWALLS SHALL BE CARRIED TO GROUND LINES SHOWN IN THE PLANS.

- 13.8.9. **MONITORING**
THE CONTRACTOR SHALL CHECK SETTLEMENTS AND HORIZONTAL DISPLACEMENT OF FOUNDATION TO ENSURE THAT THEY ARE WITHIN THE ALLOWABLE LIMIT PROVIDED BY THE ENGINEER. THESE MEASUREMENTS SHOULD GIVE AN INDICATION OF THE SETTLEMENTS AND DEFORMATIONS ALONG THE LENGTH OF THE FOUNDATIONS.

THE FIRST MEASUREMENT SHOULD TAKE PLACE AFTER THE ERECTION OF ALL PRECAST BRIDGE SYSTEM ELEMENTS, A SECOND AFTER COMPLETION OF BACKFILLING, AND A THIRD BEFORE OPENING OF THE BRIDGE TO TRAFFIC. FURTHER MEASUREMENTS MAY BE MADE ACCORDING TO LOCAL CONDITIONS.

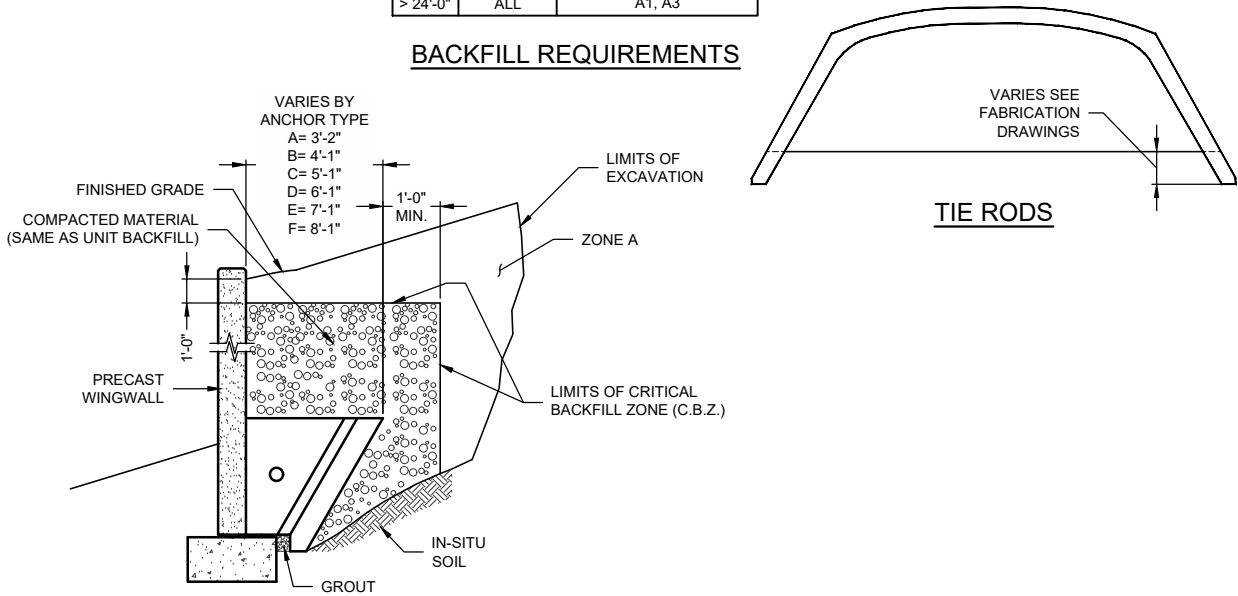
ACCEPTABLE SOILS FOR USE IN ZONE B BACKFILL

TYPICAL USCS MATERIALS	AASHTO GROUP	AASHTO SUBGROUP	PERCENT PASSING US SIEVE NO.			CHARACTER OF FRACTION PASSING NO. 40 SIEVE		SOIL DESRIPTION
			#10	#40	#200	LIQUID LIMIT	PLASTICITY INDEX	
GW, GP, SP	A1	A-1a	50 MAX	30 MAX	15 MAX	6 MAX		LARGELY GRAVEL BUT CAN INCLUDE SAND AND FINES GRAVELLY SAND OR GRADED SAND, MAY INCLUDE FINES
GM, SW, SP, SM		A-1b		50 MAX	25 MAX	6 MAX		
GM, SM, ML, SP, GP	A2	A-2-4			35 MAX	40 MAX	10 MAX	SANDS, GRAVELS WITH LOW- PLASTICITY SILT FINES SANDS, GRAVELS WITH PLASTIC SILT FINES
SC, GC, GM		A-2-5			35 MAX	41 MIN	10 MAX	
SP, SM, SW	A3			51 MIN	10 MAX	NON- PLASTIC		FINE SANDS
ML, SM, SC	A4				36 MIN	40 MAX	10 MAX	LOW-COMPRESSIBILTY SILTS



SPAN	FILL HEIGHT	ACCEPTABLE MATERIAL INSIDE ZONE B
≤ 24'-0"	≥ 12'-0"	A1, A3
≤ 24'-0"	< 12'-0"	A1, A2, A3, A4
> 24'-0"	ALL	A1, A3

BACKFILL REQUIREMENTS



WALL BACKFILL REQUIREMENTS

C:\USERS\JEREMY.JOHNSON\ONEDRIVE - THE QUIKRETE COMPANIES\DOCUMENTS\DRAWINGS\DWG 11/2/2022 10:35 AM

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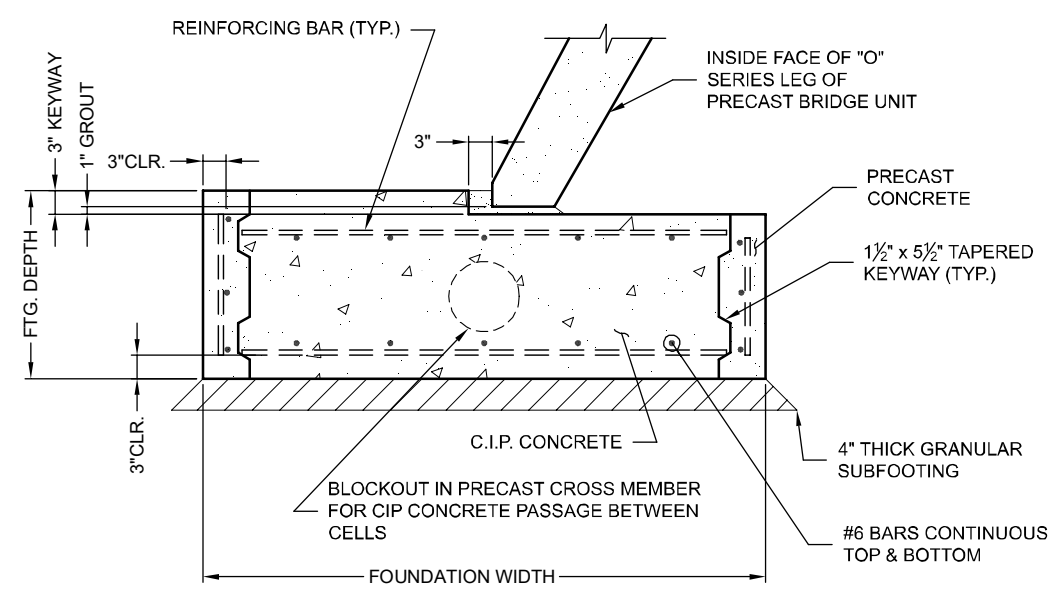
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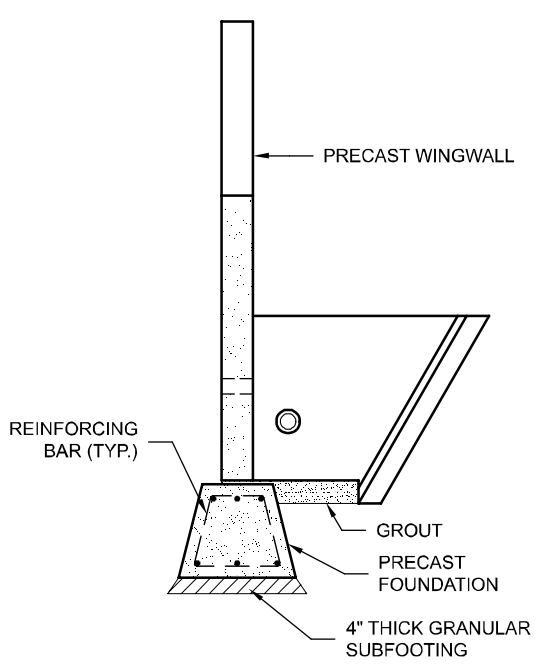
CON/SPAN O-SERIES
SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.:	D7 OF D9	

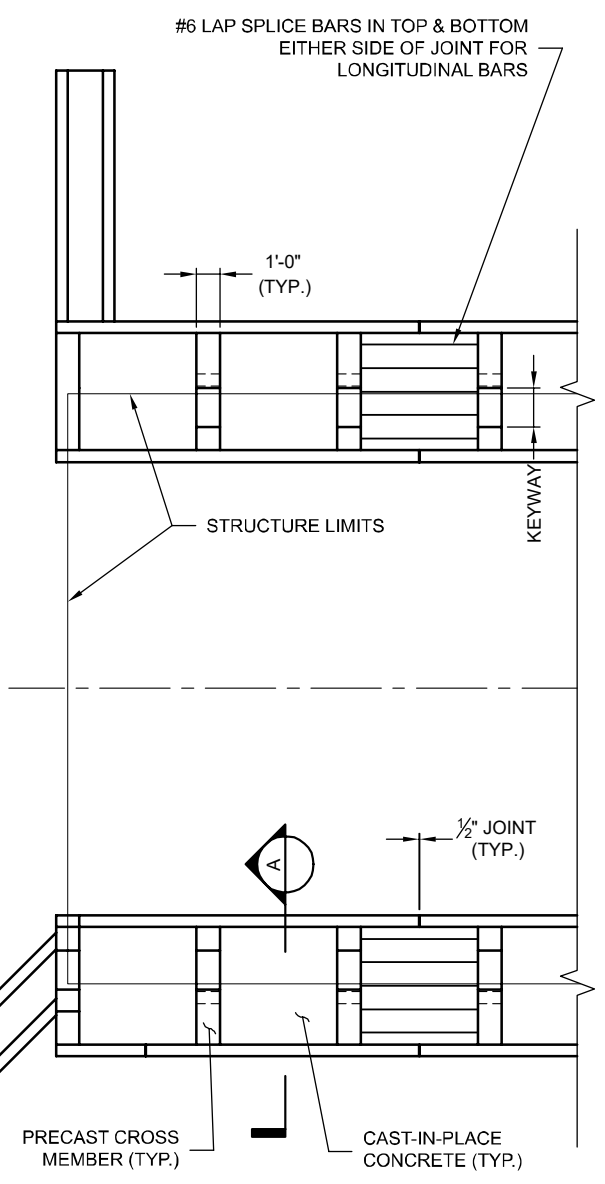
SAMPLE DRAWING ONLY



SECTION A
(NOT PROJECT SPECIFIC)



SECTION B
(NOT PROJECT SPECIFIC)



SAMPLE PARTIAL FOUNDATION PLAN
(NOT PROJECT SPECIFIC)

EXPRESS FOUNDATIONS



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EXPRESS FOUNDATION SAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D8 OF D9

SAMPLE DRAWING ONLY



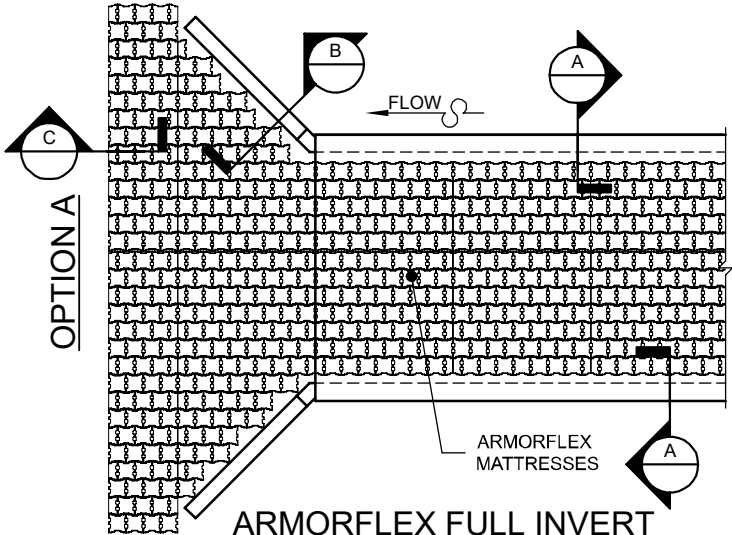
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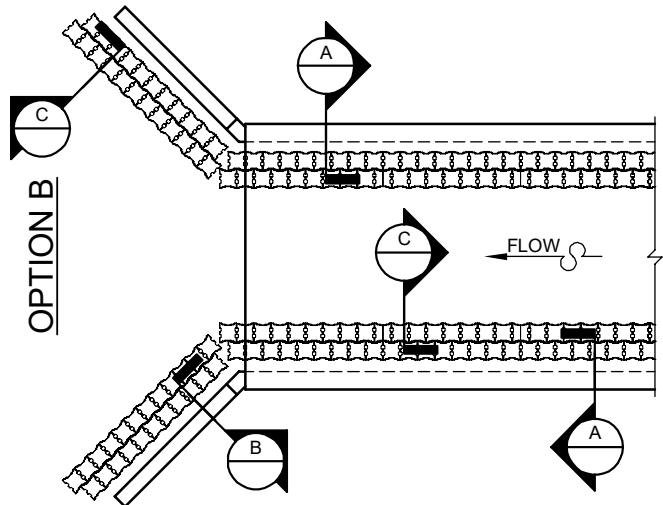
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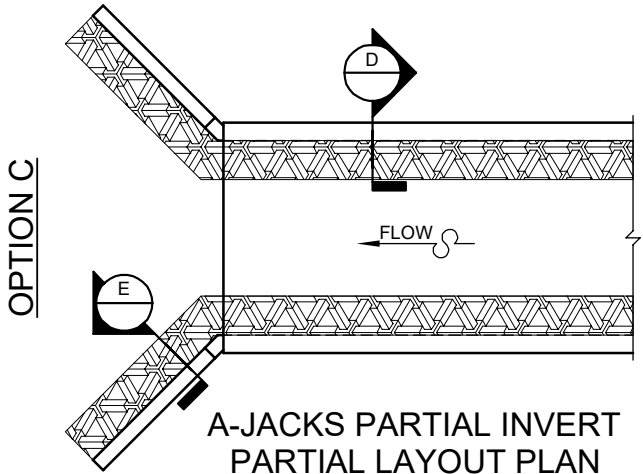
A-JACKS PARTIAL INVERT
N.T.S.



ARMORFLEX FULL INVERT
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N.T.S.

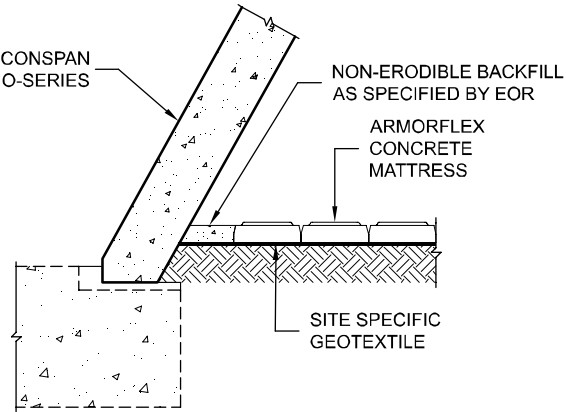


ARMORFLEX PARTIAL INVERT
PARTIAL LAYOUT PLAN
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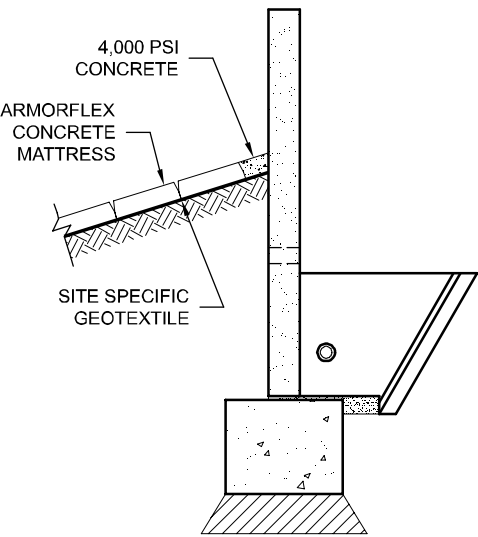


A-JACKS PARTIAL INVERT
PARTIAL LAYOUT PLAN
N.T.S.

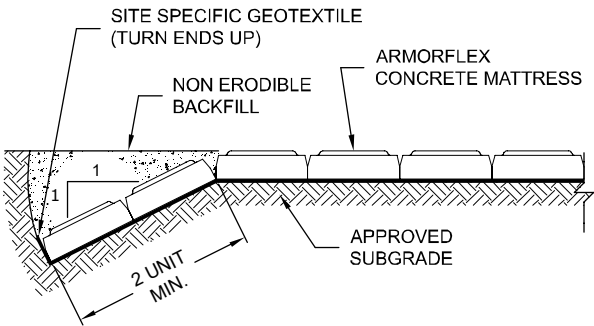
CONSIDER A COMPLETE SYSTEM WITH ARMORTEC REVETMENT



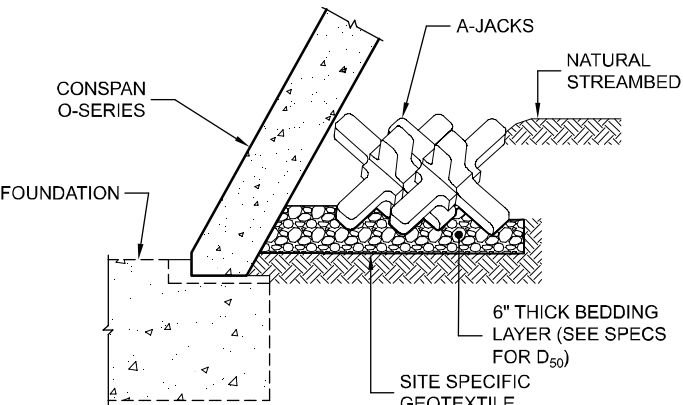
ARMORFLEX STRUCTURE TERMINATION
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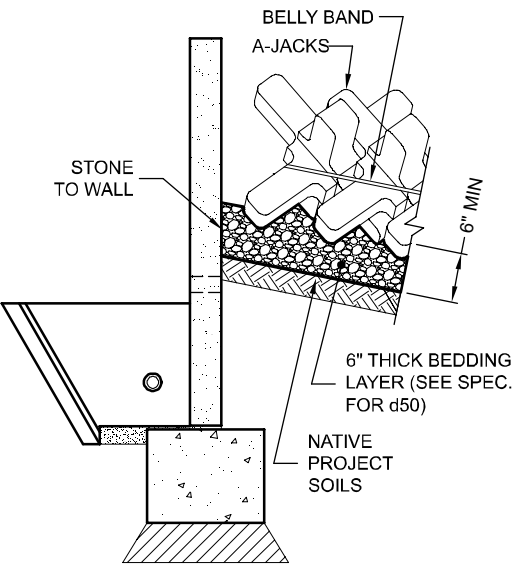
ARMORFLEX WINGWALL
TERMINATION
N.T.S.



STANDARD TERMINATION
N.T.S.



A-JACKS STRUCTURE
TERMINATION
N.T.S.



A-JACKS WINGWALL
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PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.:	D9 OF D9



J

Public Involvement Fact Sheet

Missouri Department of Transportation Wildlife Vehicle Collision Study



The Missouri Department of Transportation (MoDOT) completed a collaborative statewide study that identified hot spots for wildlife vehicle collisions (WVCs) and potential mitigation at those sites. This first of its kind analysis in Missouri was funded by the Federal Highway Administration (FHWA) Wildlife Crossing Pilot Program, the Missouri Department of Conservation, and the Land Learning Foundation. The study was conducted by HDR Engineering, Inc. and Wildlife Connectivity Institute, and it evaluated data from wildlife-vehicle crashes, carcass reports, previously completed studies, and wildlife habitat, along with evaluation of transportation ecology best management practices. The Missouri Statewide Wildlife Vehicle Collision Study provides a blueprint for Missouri to plan and build future wildlife crossing infrastructure and accommodations.

A Technical Advisory Committee (TAC) was established to closely coordinate the Study and provide project reviews, comments, and recommendations.

The Study provided recommendations to retrofit existing structures, develop, design, and construct WVC mitigation projects, with the overall goal of reducing WVCs statewide while promoting roadway safety and improving habitat connectivity.



Missouri ranked **17th** in the nation for WVCs in 2024 and 2025



Missouri has **1.2 million** acres of roadways, medians, shoulders, and adjacent spaces



Missouri has **10,454** culverts and bridges, some of which could be used to funnel wildlife below the road



Missouri has **33,811** miles of highways/interstates/state-maintained roads (7th largest in the nation)



There were **17,609** total WVCs in Missouri from 2019 to 2023



The Study was conducted in two phases. Phase One focused on the analyses of available datasets to model and map current and future conditions, identify and rank wildlife-vehicle conflict hot spots where wildlife and drivers are at risk of WVCs and where wildlife need to move across roads, and created a list of top statewide wildlife-vehicle conflict locations where mitigation was most warranted.

In Phase Two, the wildlife-vehicle conflict locations were prioritized based on various evaluation criteria, and the TOP 10 locations were visited to help develop recommended mitigation measures to both reduce crashes with wildlife and provide wildlife connectivity. A website was developed to inform the public of the study (www.modot.org/wildlife-vehicle-collision-study) with the opportunity for public comment, along with posts to Twitter/X, YouTube, Instagram, and Facebook pages.

The analyses included 25 MoDOT and TAC identified priority species that would benefit most from protected connectivity across roads. The list was used to determine which at-risk Missouri wildlife species would benefit the most from a reduction of WVCs through mitigation measures. The priority species list included mammals, birds, amphibians, reptiles, fish, and a plant (dispersed by terrestrial wildlife). Fish were included in the study due to transportation infrastructure, primarily culverts, restricting aquatic organism passage.

Several sources of data were used to determine where the WVC hot spots were. Among the data were statistics from the Missouri State Highway Patrol.

- 95% of all WVCs were deer related.
- More than 50% of WVCs occurred in dark conditions with no street lighting.
- Approximately half of WVCs occurred between October and December.
- Approximately 75% of WVCs were in rural areas.
- 95% of all WVCs occurred in areas with a posted speed limit of 45 mph or greater.

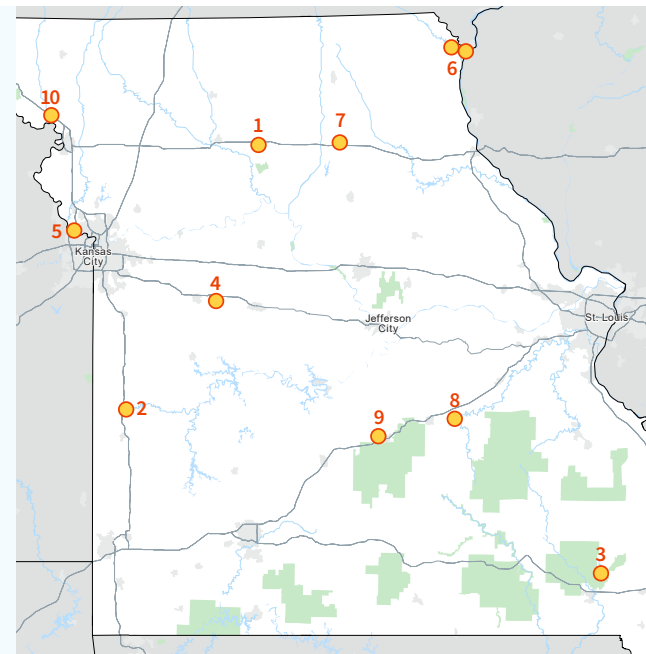
Study researchers took the available data and used ESRI's ArcGIS Optimized Hot Spot Analysis (OHSA) tool to conduct a statewide WVC hot spot analyses. The analyses identified 627 priority wildlife-vehicle conflict areas that represented the areas with the highest WVC rates and highest potential to connect landscapes for all types of wildlife. Members of the Project team then evaluated TOP 100 segments based on:

- **Land use:** whether the land is undeveloped (prioritized over developed).
- **Constructability:** whether the area is suitable for wildlife crossings.
- **Funding:** whether the segment falls within the 2025-2029 Statewide Transportation Improvement Program (STIP) project limits.



Based on the team's assessment, the following segments were chosen as the top ten priority segments.

Rank	Segment Name	County	Road	Milepost Start	MP End
1	Pershing State Park	Linn	US-36	83	95
2	Four Rivers Conservation Area (1) and (2)	Vernon	IS-49	107	114
3	Wappapello Reservoir	Wayne	MO-34	35	38
4	Whiteman AFB & Knob Noster State Park	Johnson	RT-DD	4	8.5
5	Parma Woods Shooting Range	Platte	IS-435	0	4
6	Fox River and Buck Run (1)	Clark	MO-27	0	1
6	Fox River and Buck Run (2)	Lewis	US-61	374	377
7	Long Branch State Park	Macon	US-36	122	124
8	Maramec Springs State Park	Crawford	MO-8	6	8.5
9	Roubidoux Creek Conservation Area	Pulaski	MO-17	139	141.5
10	Honey Creek Conservation Area (1) and (2)	Holt	IS-29	70	74



The Top 10 priority segments represent the locations in the state where mitigation actions could possibly be coordinated with future MoDOT projects, and where potential retrofits to existing bridges and culverts could assist wildlife movement beneath the road, thus reducing WVCs and providing wildlife connectivity. Wildlife overpasses are commonly thought of as the primary solution for mitigating WVCs, especially in the western United States where migrating wildlife cross the roads in specific corridors. Large wildlife in Missouri do not migrate, making it difficult to isolate a specific location and construct a costly overpass. Instead, retrofitting existing infrastructure is a more cost-effective solution. A typical retrofit would include constructing exclusionary fencing on both sides of the road towards an existing bridge or culvert with a suitable path below it.

Conceptual mitigation solutions were developed for each top 10 segment based on current best practices. The cost of all recommended mitigations totaled \$11.6 million, which also included ongoing maintenance, with an estimated benefit of \$43.4 million over 50 years.

To collect standardized WVC data and support future studies, MoDOT has setup the Roadkill Observation and Data System (ROaDS) application for Missouri. ROaDS was developed by the National Park Service, U.S. Fish and Wildlife Service, and Western Transportation Institute at Montana State University. Through a partnership with the Center for Large Landscape Conservation, this system is available for Citizen Science use in Missouri! Visit www.modot.org/roadkill-observation-and-data-system-roads to learn how to use the application and help us identify unreported WVCs.

